Graduate School
University of South Florida
Tampa, Florida

CERTIFICATE OF APPROVAL

———————————

Master's Thesis

———————————
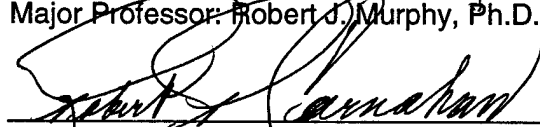
This is to certify that the Master's Thesis of

PHILIP J. PREEN

with a major in Environmental Engineering has been approved by
the Examining Committee on October 22, 1999
as satisfactory for the project requirement
for the Master of Science in Environmental Engineering degree

Examining Committee:

_____
Major Professor: Robert J. Murphy, Ph.D.

_____
Member: Robert P. Carnahan, Ph.D.

_____
Member: Wayne Echelberger, Ph.D.

REPORT DOCUMENTATION PAGE

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	3.Jan.00	THESIS

4. TITLE AND SUBTITLE
EVALUATION AND RISK ASSESSMENT OF ALTERNATIVES FOR EXTENDING THE LIFE OF LANDFILLS

5. FUNDING NUMBERS

6. AUTHOR(S)
CAPT PREEN PHILIP J

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
UNIVERSITY OF SOUTH FLORIDA

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
THE DEPARTMENT OF THE AIR FORCE
AFIT/CIA, BLDG 125
2950 P STREET
WPAFB OH 45433

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

FY99-614

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION AVAILABILITY STATEMENT
Unlimited distribution
In Accordance With AFI 35-205/AFIT Sup 1

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

14. SUBJECT TERMS

15. NUMBER OF PAGES
151

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT

EVALUATION AND RISK ASSESSMENT OF ALTERNATIVES

FOR EXTENDING THE LIFE OF LANDFILLS

by

PHILIP J. PREEN

A thesis submitted in partial fulfillment
of the requirements for the degree of
Master of Science in Environmental Engineering
Department of Civil Engineering
College of Engineering
University of South Florida

December 1999

Major Professor: Robert J. Murphy, Ph.D.

ACKNOWLEDGEMENTS

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS, ABBREVIATIONS AND ACRONYMS

6"	Six inches
α	Drainage slope
Δ	Deflection
%	Percent
%(Δ/D_p)	Percentage of deflection on collection pipe
a	Area
AAFB	Andersen Air Force Base
ACGIH	American Conference of Governmental Industrial Hygienists
AFB	Air Force Base
AFI	Air Force Instruction
AFOSH	Air Force Occupational Safety and Health
B	Drainage bedding constant
BOD	Biological Oxygen Demand
BOD_5	5-day Biological Oxygen Demand
BTU	British Thermal heating Unit
Cap	Final closure cover of landfill
CAT	Caterpillar
COD	Chemical Oxygen Demand
D	Deflection lag factor
D_p	Pipe diameter (inches)

DR	Dimension ratio
	Outer wall diameter / wall thickness (inches/inches)
E'	Modulus of the soil reaction (psi)
EPA	Environmental Protection Agency
F	Modulus of elasticity of the pipe material (psi)
$F/\Delta Y$	Pipe stiffness (psi)
ft^3	Cubic Feet
ft	Foot (feet)
gpad	Gallons per acre per day
gpd	Gallons per day
h_{max}	Maximum head on liner (feet)
HDPE	High-Density Polyethylene
HELP	Hydraulic Evaluation of Landfill Performance
in	Inch (inches)
K	Hydraulic Conductivity
L	Lateral length of drainage
lb	Pounds
LDPE	Low-Density Polyethylene
m	Meter
m^2	Square meter
m^3	Cubic meters
Mg	Mega-gram
mil	Milli-meter
mm	Milli-meter
mo	Month (months)

MSW	Municipal Solid Waste
n	Porosity (no units)
n/a	Non Applicable
NMOC	Non-Methane Organic Compounds
NSPS	New Source Performance Standards
OSHA	Occupational Safety and Health Administration
P	Pressure on pipe (psi)
PETE	Polyethylene Terephthalate
pH	Measure of alkalinity or acidity, range 0 - 14
PP	Polypropylene
ppm	Parts Per Million
PS	Polystyrene
psi	Pounds per square inch
PVC	Polyvinyl Chloride
R^2	Coefficient of determination
	Explained variation / total variation
RCRA	Resource Conservation Recovery Act
SC	Thickness of daily cover + Final Cover
sec	Seconds
SS	Suspended Solids
TSS	Total Suspended Solids
TWA	Time Weighted Average
USEPA	United States Environmental Protection Agency
VDS	Volatile Dissolved Solids
VSS	Volatile Suspended Solids
yd^3	Cubic Yards

yr(s)   Year (years)

x

EVALUATION AND RISK ASSESSMENT OF ALTERNATIVES

FOR EXTENDING THE LIFE OF LANDFILLS

by

PHILIP J. PREEN

An Abstract

Of a thesis submitted in partial fulfillment
of the requirements for the degree of
Master of Science in Environmental Engineering
Department of Civil Engineering
College of Engineering
University of South Florida

December 1999
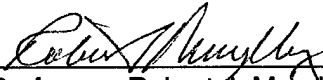
Major Professor: Robert J. Murphy, Ph.D.

Given the difficulty, as well as the high cost, to site and construct municipal solid waste (MSW) landfills it is incumbent on landfill operators to evaluate all practical measures to extend the useful life of existing landfills. This necessitates not only identifying potential methods to extend their life, but also the means to assess at what time horizons in the landfill's life such measures are cost effective. Some typical examples of methods to extend their life include; size reduction of incoming waste, improved in place compaction density, use of alternative daily cover, waste diversion, and accelerating the degradation to enhance attendant settlement on the MSW. Most, if not all, of these methods incur capital/operating costs that must be evaluated in light of the time horizon the life of the landfill can potentially be extended. The methodology for this analysis is presented using the existing landfill at Andersen Air Force Base (AAFB), Guam, as a model for the procedure.

Landfill operations pose a threat to the environment and population safety and health. A risk assessment of this site will be performed to investigate potential impacts to the air, water, and surrounding population.

During this study, current landfill operating parameters at Andersen AFB were economically compared to proposed extension methods to determine their feasibility. A site survey was performed and computer program written to model this proposal. The program was based on comparing each proposed extension alternative to the corresponding amount of additional waste that would be placed in the landfill. In order to equate a monetary gain to each alternative the $8 million capital landfill construction cost was divided by this quantity of MSW. Five preset options were built into the program for ease of use. A contracted operations option was also preset to evaluate future landfill operation outsourcing. This program was designed for landfill operators and Air Force planners to evaluate the most cost-effective alternatives to extending the

useful life of a landfill. It was found that by utilizing all of the alternatives the life of AAFB

landfill could be extended from 10 years to 48 years.

Abstract Approved: _____
Major Professor: Robert J. Murphy, Ph.D.
Professor, Department of Civil Engineering

Date Approved: _Oct 22, 1999_____

1. INTRODUCTION

1.1 Background

Based on the difficulty, as well as the high cost, to site and construct municipal solid waste (MSW) landfills, it is incumbent on landfill managers to evaluate all practical measures to extend the useful life of existing landfills. Many studies have been performed to determine the optimum methods for filling landfills and subsequently extending the useful life. To date, however, no findings or methods have been presented to compare extension alternatives, landfill risk assessment and cost effective timelines to implement alternatives.

Environmental managers must not only decide which landfill extension alternative is most feasible but also what priority will be assigned to a landfill compliance site. Landfills are not the final step in the cradle to grave concept. Production of leachate and landfill gases has a significant impact on the environment and directly impacts the health and safety of the workers and local community. It is imperative to look at the cumulative impact of a landfill when deciding on the optimum course of action.

Toward this end, the Department of Civil and Environmental Engineering at the University of South Florida has performed a site assessment of the existing landfill at Andersen AFB, Guam. The purpose of this assessment was to develop a model to aid Air Force environmental policy makers in making informed landfill decisions. The model and subsequent computer program used the landfill at Andersen AFB as a real world

case study. The computer program may be applied to any existing MSW landfill facilities used throughout the Department of Defense.

The principal objective of this program is to aid landfill managers in maximizing the useful life of any existing operational landfills. The economic benefits to landfill life extensions are significant. In the highest population densities of the mid-Atlantic regions of the United States the cost of tipping fees has risen to $150 per ton [37].

At Andersen AFB (AAFB) tipping fees are not imposed on MSW disposal. Using baseline assumptions of 177,000 cubic yards, 1,000 pounds per cubic yard compaction, and a landfill capital cost of $8 million the tipping fee would be approximately $90 per ton. This landfill cost does not reflect the final closure, yearly operations and maintenance costs, or leachate and gas control and monitoring. Maximizing the landfill and insuring proper operations will have a profoundly important environmental, health and safety, and economic impact on managing these facilities.

1.2 Objective

It is the goal of this study to explore the facets of extending the useful life of landfills and providing guidance on the economic feasibility of these various alternatives based on current landfill capacities. The problems and costs associated with siting and purchasing new landfills are constantly increasing. The "Not In My Back Yard" syndrome is spreading as the population learns more about the impacts of previous environmental program mismanagement. The U.S. Resource Conservation and Recovery Act (RCRA), which governs landfills, has established strict guidelines for operation and maintenance of MSW landfills, subsequently increasing the associated costs. It is critical to manage

an efficient operation and maximize the useful life of landfills based on the alternatives available today.

A key aspect of this study was the development of a computer program to model existing and proposed landfill operations. Four alternatives to include: alternative daily cover, shredding, compaction, and recycling/composting were investigated using this model. A fifth alternative, contracting, was also investigated and was based on an outsource application of the above mentioned alternatives.

The program provides an analysis of the economic feasibility of each proposed alternative(s) and a regression equation to be used independently of the program. This regression equation will identify the corresponding point in the landfill life where the alternative(s) are no longer feasible. Each alternative was thoroughly analyzed and an output from the model was provided in this report. The model and all supporting cell formulas were provided in Appendix 1. A thorough instruction manual was written to insure the user understands the capability, scope and limitations of the Landfill Extension Modeling program. This instruction manual can be found in Appendix 2.

A risk assessment was performed on the existing landfill. The purpose of this risk assessment was to evaluate potential adverse impacts to the environment as well as worker and public health and safety. These finding will be used as a tool by environmental managers to prioritize landfill compliance sites in accordance with Air Force guidelines. Guidance was also provided on monitoring leachate constituents. These recommendations may be useful in minimizing the resources required by the environmental sampling and monitoring programs.

1.3 Scope

This study was designed to accomplish the aforementioned objectives by creating, writing and utilizing a Microsoft Excel computer program. This format was chosen to eliminate the purchase requirement for a specialized computer program. Operational data was collected from the AAFB existing landfill. This data included recycling/diversion rates, landfill support equipment, current operational parameters, daily cover utilization and daily fill rates. This information was used as the baseline specifications for all subsequent alternative calculations, see Appendix 1. The initial input page of the program reflects this baseline data.

A baseline life expectancy was derived from this initial data. The program is centered on the quantity of volume, fill rate, and compaction density of MSW at the AAFB facility. From this information, a time to fill expressed in years and months was derived.

Data was collected through a comprehensive literature review on the alternate daily cover, shredding, compaction and recycling/compost alternatives. These alternatives resulted in various degrees of landfill life extensions. The proposed alternatives were pre-programmed into the Input Option data page in the program. A new life expectancy figure in years and months will be derived from the new data specified by these corresponding alternative(s). The user may also define the impacts of each of these corresponding alternatives on this page if field tests indicate varied performance compared to the preset values.

Preliminary data was input into the Base Recycling Program page and should be updated accordingly. This data was based on information obtained during the initial site assessment. New recycling goals may be input on the New Base Recycling Program

page. An operator may investigate the overall impact to landfill operations based on proposed changes to the recycling effort. A Community Recycling Program page was included in this program. This should be used in the event a contractual alternative would include the local community. Evaluations of the community and base waste and recycle streams should be conducted periodically. The results of these evaluations should be input in the applicable pages of the program.

The computer program will enable real time solutions to a complex problem with multiple variables. The user defines the variables based on regulatory, studied or measured findings. The program calculates the economic impact of the chosen alternatives in terms of landfill volume gained or lost. Even though a tipping fee will not be assessed in the case of AAFB there will be an associated cost per ton related to landfill installation, capping, and leachate/landfill gas monitoring/collection systems. To minimize the need for a complete economic assessment of the landfill, the program will be based on cost recovery of the initial landfill purchase, approximately $8 million.

2. LITERATURE REVIEW

To provide a thorough analysis of this study it was necessary to establish a historical link between the Landfill Extension computer program design and those studies of the past. A comprehensive literature review was performed germane to this subject.

2.1 Recycling

The U.S. Resource Conservation and Recovery Act (RCRA) of 1976, which amended the 1965 Solid Waste Act, resulted in stricter control of MSW land disposal. With this stricter control of landfill operations and associated increase in costs, the national trend became recycling [36]. In essence, keep the waste out of the landfill to help offset the rise in disposal fees.

Recycling opportunities exist for glass, scrap metal, aluminum, construction and demolition debris, yard waste, plastics, wood, and paper products. In many states there are mandated, 100 percent diversion rates for yard and construction/demolition waste. The sole intent of these mandates was to maximize and extend the life of existing landfills. As mentioned earlier, this equates to a significant monetary return in dollars per ton of mass diverted.

Over the past two decades many studies were performed on the economics associated with recycling efforts. Due to weak markets for secondary materials the costs associated with recycling are high. Recycle material prices may vary as much as a

factor of two over a one-year time [39]. Studies indicate the typical national average costs for recycling programs ranged from $98 to $138 per ton of waste recycled [15]. This figure is significant when one considers the national average cost of landfilling ranges from $20 to $53 per ton [15].

Recycling is generally accepted as the only environmental solution but there is a limit to the amount of recycling that can be achieved economically [4]. A cost-benefit economic analysis should be performed at any facility to determine the economic feasibility of a recycling program. This study should indicate realistic levels of recycling effort given the geographical location, associated equipment costs, and operations and maintenance costs. These findings must be compared to the overall costs of disposal. From this information, a value may be derived to show at what point in the landfill life the alternative(s) are no longer feasible.

The federal hierarchy for integrated MSW management is source reduction, recycling, waste combustion followed by landfilling. This hierarchy was established to reduce the amount of material requiring landfill and AAFB follows this philosophy. For many recyclable materials the economics associated with combustion far exceed the corresponding costs of recycling. This point will be addressed in the following sections.

Landfill revenue will be based on the sale of recycled material and subsequent gain in landfill space. Even though the recycling portion of a landfill operation program may not be profitable, the overall landfill operation may still show a profit based on the associated mass diversion and landfill tipping fee. Table 1 shows the percentage by weight and the corresponding recycling rate of each component of the AAFB waste stream. The overall recycling rate for AAFB was 35.2 percent.

Table 1 AAFB Recycling Program

Andersen AFB Recycle Program		
Component	% by Weight	Recycle Rate (%)
Food Wastes	17.5	0.0
Containers		
Aluminum	2.0	90.0
Bi-metal/tin	3.1	0.0
Glass	10.4	95.0
Plastics	1.1	0.0
Subtotals	16.6	71.4
Paper Products (other than containers)		
Cardboard	8.4	95.0
Paper/Magazines	5.1	75.0
Mixed	19.4	0.0
Subtotals	32.9	35.8
Plastics (other than containers)	10.1	0.0
Scrap Metals (other than containers)	1.6	75.0
Wood		
Pallets/Crates	2.0	100.0
Other wood	1.6	0.0
Subtotals	3.6	57.1
Dry Cell Batteries	0.2	0.0
Miscellaneous		
Construction Debris	1.9	100.0
Diapers	4.2	0.0
Glass (other than containers)	0.2	0.0
Rubber (other than tires)	0.2	0.0
Textiles (rags, clothing)	0.9	0.0
Yard Waste (grass, fronds)	6.6	100.0
Other	3.5	0.0
Subtotals	17.5	51.4
Totals	100.0	35.2

2.1.1 Paper Recycling

On a weight basis, paper constitutes the largest component of municipal solid waste, from 25 to 40 percent [39]. AAFB reported 928,855 pounds of cardboard collected in 1992. The corresponding recycle rates for cardboard and paper/magazines were 95 and 75 percent. The overall recycle rate for the paper product category was 36 percent, see Table 1. The main types of paper currently recycled are newspaper, corrugated cardboard, high-grade paper, and mixed paper. The leading sources of cardboard are the Defense Commissary Agency and the Army-Air Force Exchange Services. These agencies currently collect and bail their own material. The bails are

collected at the AAFB recycling center. Once a sufficient quantity of material is collected a buyer will transport and ship the material to a recycling facility.

From a national economic standpoint there is a larger return on investment from the energy derived from paper combustion than recycling [23]. The costs associated with paper recovery methods are significantly high compared to using primary materials to produce paper. There are no practical alternative uses of recycled paper.

2.1.2 Plastic Recycling

Typically plastics constitute seven percent by weight of the total MSW stream [39]. AAFB currently has no plastic recycling option due to absence of a secondary or local market. Plastics have a significantly high volume to weight ratio and are not a practical recycling option. Even though most plastic containers have been coded from 1-7 based on the material used during production, the principle types of plastics now recycled are polyethylene terephthalate (PETE) and high-density polyethylene (HDPE).

When performing a cost-decision economic analysis it would be reasonable to assume that nearly 100 percent of disposed plastics could be incinerated when compared to the recycling alternative [23]. Ultimate disposal of plastic is inevitable and it will remain a major component of MSW regardless of recycling efforts.

Certain plastics, primarily recycled polyethylene, may be mixed with paving grade asphalt cement to form modified asphalt cement. The goal of this modified asphalt was to reduce rutting and increasing durability [14]. Other uses of recycled plastics according to plastic code include the following [39]:

A   PETE (polyethylene terephthalate): Polyester fibers used to manufacture sleeping bags, pillows, quilts, cold weather clothing, carpet backing and fibers, molded products, polyisocyanurate insulation boards, films, strapping, food and non-food containers, engineering-grade plastics for the automotive industry

B   HDPE (high-density polyethylene): Grocery sacks, pipe and Molded products

C   PVC (polyvinyl chloride): Nonfood containers, floor tiles, garden hose, flower pots, toys, drainage pipe, fittings, moldings, sheet and injection molded parts.

D   LDPE (low-density polyethylene): Garbage bags, plastic film sheets to protect cargo from tie down straps

E   PP (polypropylene): Used in low-specification products to include plastic lumber, outdoor furniture, pilings, posts, fencing, and batteries

F   PS (polystyrene): Foam foundation insulation board, office accessories, food service trays, trash receptacles, toys, and injection molded products

G   Other (mixed plastics): Outdoor furniture, tables, car stops, Fence posts, retaining timbers, pallets and stakes.

2.1.3 Glass Recycling

Glass constitutes approximately eight percent by weight of MSW [39]. AAFB has a glass container substitution program with a reported diversion of 357,840 pounds in 1992. The corresponding recycle rate for glass container recycling was 95 percent, see Table 1. Glass is dense, especially when compared to the other recyclable materials such as plastic and aluminum. Diversion of glass was key to saving landfill volume. Many studies have shown glass and plastics were the leading bulk contaminant of

compost. Active diversion of glass will minimize future negative impacts on potential composting programs.

Potential local uses for the recycled glass were identified. Asphalt contractors have used glass as an aggregate in a typical range of 10 to 15 percent in asphalt mixes [23]. The glass did however demonstrate a tendency to strip or loosen from the asphalt binder because it would not adhere to the asphalt. Glass aggregate may also be used as a drainage bed around leachate recirculation or water draining lines.

2.1.4 Scrap Metal Recycling

Scrap metal comprises 10 percent by weight of the total MSW stream [39]. Metal recycling has steadily increased over the past two decades and metal recovery from these materials had increased by 41 percent [33]. The purity and quality control during collection of secondary metals is continuously improving. For this reason, manufacturers are finding it more economical to use secondary scrap metal then primary metals during production. The market for secondary metals is expected to exceed the market for primary metals in the next decade [33].

AAFB has a scrap metal collection program with a reported 112,991 pounds of scrap metal diversion per year. The corresponding recycle rate for scrap metal recycling was 75 percent, see Table 1. Currently there are no scrap metal markets available to AAFB and the base is collecting and storing this material.

2.1.5 Aluminum Recycling

In communities with established recycle programs, aluminum cans constitute less than one percent by weight of the MSW [39]. Aluminum recycling is the most common recycling alternative due in part to a cost effective recycling system. Public support of aluminum recycling is the strongest because of the associated economics and familiarity.

Like scrap metal, aluminum is just as economical to manufacture from secondary material as it is from primary material. AAFB has an aluminum can collection program with a reported 158,877 pounds recycled in 1992. The corresponding recycle rate for aluminum can recycling was 90 percent, see Table 1.

2.1.6 Yard Waste Recycling

AAFB diverts nearly 100 percent of yard waste collected. Typically this equates to seven percent by weight MSW [39]. Yard wastes, like plastics, have a high volume to weight ratio [23]. The primary recycling opportunities for yard wastes are for the production of compost, landscape mulch and intermediate landfill cover material.

AAFB has a yard waste mulching program with a reported 452,683 pounds of yard waste diverted in 1992. Based on the diversion of yard waste from the MSW the corresponding recycle rate was approximated at 100 percent, see Table 1. There is currently no market available for composted yard waste. Yard waste is collected and stored at the landfill site. This collected yard waste will decompose and could eventually be used in the construction of the final cover of the AAFB landfill.

2.1.7 Wood Recycling

Wood wastes are a major component of yard wastes and account for more than 25 percent of construction and demolition wastes [39]. Wood waste on AAFB is primarily in the form of pallets and creates which is shredded using a tub grinder. AAFB has a wooden pallet collection program with a reported 3,658,158 pounds of wood diverted in 1992. Based on the diversion of wood pallets from the MSW the corresponding recycle rate was approximated at 100 percent, see Table 1. The overall recycling effort for wood products was 57.1 percent.

AAFB had used a tub grinder to chip the wood pallets. The tub grinder is currently non-operational and this practice was ceased. The wood pallets are stored on site and are available for future reuse or chipping. The primary use of wood and yard waste mulch is landscaping. Many studies have shown this mulch may also be used as landfill cover, intermediate cover, and as a bulk agent for compost [35].

2.1.8 Construction and Demolition Recycling

Construction and demolition waste products are predicted to become the largest waste category [6]. AAFB has a construction debris separation program with a reported 3,658,158 pounds diverted in 1992. Based on the diversion of the construction and demolition portion of MSW the corresponding recycle rate was approximated at 100 percent, see Table 1.

Most materials such as spoil, naturally occurring, or chemically inert, man made, may be reused without treatment. Leachate produced form these materials have been found not to change the natural environment and may not require landfill [6]. It is

important to note some states, including Florida, do require lined landfill disposal of all construction and demolition waste.

Wood, paper and plastic from these wastes exert high leachate concentrations of various constituents. For this reason this material does require proper landfill disposal. Gypsum, found mainly in wallboard, has a high lime concentration and subsequently requires landfill disposal.

All hazardous construction waste must be treated according to the same guidelines as any hazardous waste and may not be disposed in a landfill prior to pretreatment. There are alternative uses for construction and demolition debris, which may be implemented at minimal costs.

Gypsum, due to its inherent lime content, is used in many areas to supplement crop soil where pH adjustments are required [35]. Roofing shingles contain 19-30% liquid asphalt, filler and aggregate, all of which are present in hot mix asphalt [14]. Reclaimed asphalt pavement and recycled concrete may be recycled in place or used as road base [14].

2.2 Composting

Municipal Solid waste typically contains 70 to 80 percent organic material [39]. Typically MSW composting is limited by the availability of a market or even by local demand to distribute the material free of charge. There are many environmental concerns about compost quality due to the type of waste in the MSW stream. The role of composting as a diversion mechanism has decreased over the past decade with many plants closing down operations [4].

AAFB does not currently have an MSW composting program. A study was performed on the waste and it was proposed approximately 1,987,878 pounds of MSW could be diverted yearly. Based on the calculated daily landfill input of 13.1 tons per day this would be equal to a 21 percent annual diversion. In a separate study, a compost program resulted in a total waste stream diversion of 46 percent [5]. During this study, non-recyclable paper was included in the compost material. According to the study this did not have a negative impact on the overall paper recycling program or compost quality.

The end uses for MSW compost are usually limited to agricultural uses or land reclamation [39]. Operations presented in the literature review either sold or gave away the finished product. Aside from the compost chemical characteristics, there were problems with residual plastics and glass due to improper separation. Typically wood chips are added to the composting process for bulking purposes. This enhances mixing and creates void spaces in the compost matrix. This also creates a more aerobic mix and subsequently reduced odor.

Many of the pallets, which could potentially be used for this process, have been chemically treated. One study addressed this issue in a pilot study. Results indicated that composting of spent press-molded, wood fiber pallets bonded with urea-formaldehyde showed no formaldehyde emissions and compliance with environmental guidelines [21].

One additional alternative to disposing of yard waste is composting with biosolids from the Guam municipal wastewater treatment plant. A study was conducted showing a yard waste:biosolid composting ratio of 3:1 minimized odor and improved compost characteristic [30]. Leaching of several metals was observed; however, only lead was observed in the runoff at concentrations above the maximum contaminant levels [30].

A pilot project would need to be performed to determine the cost-effectiveness of a composting program. Factors to consider for the composting program include: materials to compost, collection of materials, final product quality, operations and maintenance costs, as well as a cost analysis to determine the what level of diversion would be cost effective [20]. One study suggested the economics of a compost facility would not favor a small volume operation due to the initial capital costs associated with compost turners and shredders [31].

2.3 Incineration

The EPA studied incinerator operations with capacities of less than 50 ton per day in 1976 [18] and a study was performed on facilities operating incinerators with less than 550 ton per day capacity in 1991 [17]. Published findings in both studies on capital and annual operating costs were closely related. Current technology for small-scale incinerators include a modular facility construction based on the required daily capacity. A significant disadvantage to incineration is the public perception of environmental pollution and associated health risks. There are also significant costs associated with air pollution control equipment required by the EPA.

Mass burn facilities do not require separation or preparation of the MSW prior to burning. Based on a study of 77 U.S. plants using this technology, an industry standard 85 percent efficiency energy output was realized with an overall average mass reduction of 70 percent [17]. These shop fabricated modular units have the lowest overall capital costs in comparison with other types of similar capacity. The other units in this category were the field-built, rotary, and refuse derived fuel plants. The average national capital

cost of these units adjusted to 1999 values was $65,000 per ton. The average national operating cost adjusted to 1999 values was $14,700 per ton per day.

The energy derived from these plants will produce a revenue base for operations. Under the Public Utilities Regulations and Procedures Act, electrical utilities are required to purchase electricity produced by waste-to-energy facilities. In 1989 the typical agreed prices varied from three to four cents per kilo-watt hour [4]. The equivalent 1999 costs based on a Chemical Engineering Cost Price Index of 391.5 the price may vary from 4 to 5 cents per kilo-watt hour [8]. Typical studies show the thermal energy equivalent of MSW to be 5,850,000 British thermal heating units (BTU) per ton or 1.1 barrels of oil per ton of refuse burned [7].

2.4 Leachate Recirculation

Many studies have shown the benefits of leachate recirculation include accelerated waste stabilization and gas production rates, landfill volume reduction, decreased long-term liability, and improved leachate control. Leachate recirculation systems must be designed into the existing fill with a minimization of low permeable material usage for the intermediate and daily covers. There are four phases associated with the life of a landfill.

2.4.1 Phase 1 – Aerobic Phase

This phase is usually defined as the time for the moisture content to reach field capacity. The typical time frame for this phase is approximately 50 to 100 days [29]. The typical moisture content of incoming MSW varies between 20 to 40 percent. The

field capacity is defined as the total amount of moisture that can be retained in a waste sample subject to the downward pull of gravity. The typical field capacity for MSW varies from 60 to 70 percent. Once the MSW reaches field capacity a microbial community can be supported. During this phase oxygen is entrained in the MSW matrix and aerobic decomposition is occurring.

2.4.2 Phase 2 – Anoxic Phase

During the anoxic phase, the MSW transfers from an aerobic, with oxygen, to an anaerobic, with out oxygen, phase. The typical timeframe for this phase is approximately 50 to 150 days [29]. This occurs when the oxygen in the void spaces is completely utilized. The primary electron acceptors become nitrates and sulfates instead of oxygen. There is an increase in volatile fatty acids to include propanoic, acetic, and butyric. Carbon dioxide levels increase and fill the void spaces. Leachate characteristics include a pH in the range of 5.5 to 6.5 and a high total dissolved solids concentration.

With this decrease in pH there is a corresponding transition of metals to their ionic form. While a metal is in this ionic form it is mobile and travels from the MSW matrix and subsequently into the leachate. A porbaix diagram can be used to determine which metals are in free ionic form at various pH levels.

2.4.3 Phase 3 – Methanogetic Phase

There is a conversion in this phase from the acid forming to methane forming bacteria. The typical time frame for this phase is approximately 150 to 600 days [29].

The result is a significant methane and carbon dioxide production. During this phase the pH increases and there is a subsequent reduction of the sulfate and nitrate to sulfides and ammonia. This change in pH results in the hydrolysis, oxidation or complexation of the metals. In this form, the metals will no longer be mobile in the matrix. The metals will usually precipitate out in the form of fulvic or humic structures.

2.4.4 Phase 4 – Stabilization Phase

During this phase the nutrients and substrate are the limiting factor and biological activity is minimal. The timeframe to reach this phase is typically in excess of 600 days [29]. Methane production will be significantly lower and constant over time. The leachate will have the following characteristics: pH 6.7 to 7.5; low total dissolved solids; and low volatile fatty acids. Carbon dioxide concentrations will also be significantly lower and more stable.

Landfills using leachate recirculation follow the same phases as described above except at an accelerated cycle time. Many studies have shown the time required for landfill stabilization can be reduced from several decades to 2-3 years [27]. A study was conducted to quantify this reduction in terms of Chemical Oxygen Demand (COD) half-life. In conventional landfills this half-life was approximately 10 years. In a pilot study where leachate recirculation was implemented the half-life ranged from 230 to 280 days [28]. A separate study validated these findings by showing the degradation of MSW is a function of both kinetics and recirculation rate [10]. It has been shown that recirculation with the addition of nutrient materials such as phosphate and nitrates do not have a significant effect on overall degradation [29].

There is tremendous application for this technology in current landfill operations. By speeding up the stabilization process possible long-term adverse environmental impacts are minimized. Studies have also revealed recirculation of leachate enhances the reduction of sulfates to sulfide [29]. The metals will be released from the MSW matrix as described above; however the sulfides will inhibit the transport of these metals. The subsequent result is a decrease in free metal ions released in the leachate.

Landfill reclamation and expense of maintaining the integrity of the final cover are facilitated by the accelerated stabilization of the landfill. An annual cost saving of approximately $2,500 per acre is expected at landfills utilizing recirculation due to reduced long-term care and liability. The typical capital cost for installing a recirculation system in 1999 dollars ranged from $35,000 to $50,000 per acre. It is also estimated operations and maintenance should begin at approximately $2,500 per month but reduce over time [24].

Studies have indicated potential problems associated with recirculation systems. Problems arising from aggressive leachate recirculation include the following: leachate seepage from the slope; complete slope failure; increased odors; interference with landfill operations; and exceeding the capacity of the leachate collection system. Proper management must be utilized to minimize problems and insure the fill is maintained at field capacity.

The Hydraulic Evaluation of Landfill Performance (HELP) model can be used to calculate the optimum quantity of leachate recirculation [25]. The daily precipitation quantity can be increased proportional to the proposed quantity of leachate recirculation. The operator can then verify the 12" head on liner, required by state and federal regulations in the U.S., is not exceeded by the proposed recirculation quantity. HELP model, version 3, can accommodate this calculation; however it only allows the

recirculation rate to be specified as a percentage of leachate collected and does not allow a constant rate of leachate recirculation to be modeled [25].

Various methods can be used to apply leachate to the MSW. The least preferred method is spraying the leachate on the working face of the landfill. The concern of health and odor problems has prompted the EPA to ban this practice in most areas [28]. Surface infiltration ponds may be used, however, due to saturation of the underlying matrix must be moved frequently.

Vertical injection wells were at one time the most popular engineering approach to leachate recirculation. Many problems with this method were identified. They include damage to the linear system; uneven dispersion; short-circuiting; interference with landfill operations and compaction; and proper spacing of the system.

Horizontal subsurface is the preferred method for leachate distribution in the landfill. Horizontal trenches are dug and filled with tire scrap, crushed glass aggregate, or pea gravel. Leachate is fed through a piping system by gravity or pumping. These systems can be used during active landfilling or at closure [27].

Recirculation has also been shown to reduce the costs associated with leachate treatment. Leachate recirculation produced a more consistent effluent from the landfill. During the early years of leachate treatment, municipal wastewater treatment plants were used to handle the biological components of the leachate. In later years, a physical-chemical treatment procedures were employed to treat the leachate [24]. This will reduce operation costs associated with the leachate treatment process. Studies are currently being performed to investigate the benefits of recirculating clean water through a stabilized landfill for a set period of time to ensure removal of all transportable contaminants [24]. No information was found on the combined effects of shredding and recirculation. AAFB currently does not have the capability for monitoring leachate flow

from the landfill. Calculations pertaining to leachate production or recirculation will not be made in this study.

2.5 Alternative Daily Cover (ADC)

Duffy stated, "With all of the cost and space benefits of alternative daily cover (ADC), it seems hard to believe that some landfill operations continue to use soil as daily cover" [11]. Typically, workers who use soil will spend 3 hours placing and removing the daily cover each day. This does not even consider the time it takes to scrap and move the soil and is a significant strain on operations and maintenance funds.

State and federal regulations in the U.S. require a 6 inch thick layer of daily soil cover to properly close the working face of the fill at the end of the working day. The purpose of daily cover is to control disease vectors and liter dispersion [45]. Wright defines vector as, "any insect or other arthropod, rodent or other animal of public health significance capable of causing human discomfort, injury or capable of harboring or transmitting the causative agent of human disease" [45]. The cover also aids in minimizing odors, moisture infiltration and fire risks. Currently AAFB is using a CAT D5 to apply/remove the daily soil cover.

Daily cover removal is not an efficient process. It is estimated that 10 to 20 percent of the soil remains in the fill [11]. In terms of wasted air space and a typical tipping fee this will cost the landfill facility a significant sum of money annually. It is imperative for landfill managers to consider the following alternative daily cover options.

Synthetic ADC materials fall into five broad categories: degradable and disposable thin films, high density polyethylene (HDPE) reusable sheets, reusable non-woven geotextiles, spray foam applications, and pulped paper spray applications.

2.5.1 Tarp Systems

Degradable and disposable thin films, high-density polyethylene (HDPE) reusable sheets, reusable non-woven geotextiles are the three types of tarp systems currently available. The life of these tarps will vary with the type of material selected and operating conditions.

Placement of these tarps is performed by the work crew or by a spreader attached to a bulldozer. The average time it takes to place and remove these tarps is 45 minutes per day. Once the service life of the tarps has expired they can be shredded and disposed in the landfill. With a typical service life of 6 months (light weight material) to 3 years (heavy weight material) tarps may need to be replaced frequently. Tarps constructed of heavy weight material and steel cable braiding withstand wind speeds up to 30 miles per hour. Tarps constructed of light-weight material would require supplemental anchoring.

The Non-Woven Geotextiles are the most durable of the three tarp systems. They are interlaced with steel cables to provide weight to compensate for windy conditions and enhance the ease of placement when using the bulldozer. The Highland county landfill in Florida utilized these tarps and stand by there durability. It is important to note that Florida has nearly the same climate as found in Guam.

2.5.2 Spray Applications

Spray foam and pulped paper spray applications are the two types of spray on covers available. Spray foam uses an inert chemical mixed with water to form the foam.

The pulped paper spray uses biodegradable polymers mixed with post consumer fibers and pulps. Both of these applications cover the working face with an inert foam layer.

The advantages of these systems are quick application and high performance. The foam will decompose over time using almost no fill space. This material is very effective against blown litter and disease vectors.

The disadvantages of these systems are the need for extensive application equipment and storage facilities. There is also a high capital cost and poor performance in windy climates. The operational parameters such as climate will be specific to the selected equipment.

Small to medium sized landfills, less than 1,000 tons per day as AAFB is, should first consider tarps, sheets, or alternative daily cover fabrics, as they required no additional equipment acquisition or leasing [11].

2.6 Final Cover

RCRA, subtitle D, for MSW requires a final cover, cap, to have an equivalent or lower permeability than the lowest permeability on the liner system. The regulations do allow the governing regulatory agency to consider and approve an alternative final cover as long as it meets the general performance standards. Traditionally a clay liner is used to meet this requirement. The major disadvantage to this system is the inherently high costs and difficulty in constructing. Due to weather conditions these covers are prone to fail over time. Settling of MSW will also cause covers to sag and crack over time.

Preliminary studies conducted at Kirtland AFB have identified two barriers that cost less than half of a clay cover and the long-term performance are expected to be better [12]. Data will be collected on these systems over the next five years.

The first system called the anisotropic test cover has the following layers: vegetation; 6 inch topsoil/gravel mixture layer; 2 foot native soil layer; 6 inch fine sand interface layer; 6 inch pea gravel sub-layer; geotextile, geonet; and 40 mil geomembrane.

The second system called the evapotranspiration soil cover has the following layers: vegetation; 6 inches topsoil; 3 foot native soil layer; geotextile; geonet; and 40 mil geomembrane.

2.7 Shredding

Modern day landfills are literally tombs for MSW. With the proliferate use of plastic garbage bags, garbage is literally sealed from the effects of comingled waste decomposition. Shredding is a significant alternative to extending the useful life of a landfill and enhancing the decomposition of the material. Multiple studies have shown shredding will increase the density of MSW by 15 percent over unprocessed refuse [16]. When shredding was used and no soil daily cover was applied a 29 percent increase in density was realized. In addition to the space and monetary savings of shredding there are many other advantages. Studies have shown there is a significant reduction in the number of birds, rodents and other disease vectors attracted to landfills where shredding is used [19]. Thus, shredding would minimize the potential spread of pathogens by disease carrying vectors. Although currently not a problem at AAFB, this is important for preventing potential bird strikes by aircraft considering the close proximity of the landfill to the runway. Other advantages include a reduction of wind-blown refuse and the reduced potential for landfill fires.

The most commonly used shredding equipment is the horizontal shaft, swing-hammer, Flail hammermill [32]. A common name for this piece of equipment is the Flail hammermill. This shredder is an impact device that is rotated at high speed. The hammers extend radially outward from the shaft due to centrifugal force. When the hammers hit the refuse there will be sufficient force to crush or tear them. The velocity of these hammers is such that objects do adhere to them.

The greatest advantage to the Flail hammermill is that the hammers are not fixed. This versatility allows them to handle large dense objects without causing irreparable damage to the equipment. If a large object passes into the system the hammers will rebound off of the object. If the hammers were fixed they may be sheared off during the impact. The waste is further reduced in the inner chamber until it is small enough to fall through the preset grating. The literature showed specific energy consumption data for full-scale commercial equipment to range from 5 too greater than 30 kilo watt - hour per ton [34].

Dade County, Florida has used three Williams horizontal hammermills, each handling 70 tons per hour since 1981 [19]. The results of this study verified previous findings on the use of shredders. One significant disadvantage to using a shredder is the potential for contaminating compost material. This occurred when batteries or other hazardous waste products were crushed.

2.8 Compactors

Selection of compaction equipment is critical to the proper management of a landfill. Improper equipment selection will lead to under utilization of landfill space and could potentially lead to higher operational and maintenance costs [22].

AAFB currently utilized Cat D5 track type tractors. These are very versatile pieces of equipment. The typical range of compaction of MSW for this equipment is 900 to 1,100 pounds per cubic yard. This equipment also has an effective slope limitation of 4 to 1. Reduced compaction potential is caused by a lower typical load weight of 30,000 pounds [44].

MSW Compactors are designed for the rigors of landfill operations. The typical range of compaction of MSW for this equipment is 1,200 and 1,600 lbs/yd3. The typical loaded weight of this equipment is in excess of 45,000 pounds. An effective slope of 3 to 1 can be realized using this equipment. MSW compactors are usually recommended when higher compaction densities are required due to limited landfill space [22].

As described earlier in the leachate recirculation section, an increase in moisture content of the incoming refuse will increase the compaction characteristics. Many landfill managers find a slope of 3 to 1 using a compactor will provide maximum compaction and a certain degree of shredding. Operator knowledge of the daily refuse and spreading characteristics will also maximize the compaction of the MSW. The typical depth of waste should not exceed two feet while spreading it on the working face of the fill.

Compaction density can best be described with the following equation: weight ÷ volume = density [38]. In order to maximize the compaction density, equipment operators should experiment with different methods. During each experiment the weight of incoming MSW should be measured. While placing the refuse, a combination of passes should be evaluated to determine the optimum number of pass to compaction ratio. Prior to and after the refuse is placed measurements should be taken to determine the volume of the working face. By dividing the incoming waste by this volume a

compaction density can be calculated. This step should be repeated to find the optimum compaction process.

2.9 Landfill Gas

RCRA, subpart D, outlines requirements for landfill gas emission criteria. Methane concentrations must be 25 percent of the Lower Explosive Limit (LEL) in on-site structures and must not exceed the LEL at site boundaries. Landfill gas must be monitored quarterly and if the above criteria is exceeded a corrective action plan must be submitted within seven days.

The new source performance standards for new MSW landfills are governed by 40 Code of U.S. Federal Regulations (CFR) 60, subpart WWW. AAFB must comply with this regulation since they became operational after May 30, 1991. The purpose of these standards was to monitor Non-Methane Organic Compounds (NMOC's) emissions. NMOC may not exceed 55 tons per year. The Scholl Canyon Model may be used to estimate NMOC emissions from a landfill [42]. This model is included in the LEM program and the output is shown on the Summary page. The EPA defines the Scholl Canyon Model equation and variables as follows.

$$M_{NMOCs} = 2 * L_0 * R * (e^{-Kc} - e^{-Kt}) * C_{NMOCs} * 3.595E10^{-9} \qquad (1)$$

M_{NMOCs} Mass emission rate of NMOC,

L_0 Refuse methane generation potential, m^3/Mg refuse
EPA default value = 170 m3/Mg

R   Average annual acceptance rate, Mg/yr

K   Methane generation rate constant, l/yr
EPA default value = 0.05 l/yr

c   Years since closure (c = 0 for active and/or new landfills)

t   Age of landfill, years

C_{NMOCs} Concentration of NMOC, ppm as hexane

                     EPA default value = 4,000 ppm

3.595E-9   Conversion factor

There are three tiers associated with these standards as defined in 40 CFR 60 and Air Emissions from Municipal Solid Waste Landfills – Background Information for Final Standards and Guidelines [41]. The following sections provide a summary of these three Tiers as defined by the regulations.

2.9.1 Tier 1

Tier one requires the performance of desktop calculations using EPA's default values. If NMOC emissions exceed 55 tons per year, the landfill has two options. Option 1 is to continue with tier 2 and option 2 allows the landfill to implement gas control procedures.

2.9.2 Tier 2

Tier two requires on-site sampling for NMOC concentrations. These concentration values are then used in the Scholl Canyon Model equation. The landfill extension program allows the user to input these concentrations on the New Loading page. A minimum of two samples, taken in accordance with method 25C, must be taken every 2.5 acres of landfill surface area. If the NMOC emissions are less than 55 tons/year no further action is required other than repeating the test every five years. If

the NMOC emissions exceed 55 tons/year, the operator may either proceed to tier 3 or install an emission control system.

2.9.3 Tier 3

Tier 3 requires a specific determination of the methane generation of the landfill. This value will be derived from method 2E test results. The calculated value of methane generation will be used as the K constant in the Scholl Canyon Model. The landfill extension program allows the user to input this concentration on the New Loading page. If the NMOC value is less than 55 tons per year no further action is required other than repeating the test every five years. If the NMOC value is greater than 55 tons per year the landfill must install a control system.

2.10 Stress Analysis on Leachate Collection System Pipes

A major concern of filling the AAFB landfill to optimum capacity was the stress that will be placed on the pipes of the leachate collection system. Six inch HDPE pipes are used to drain leachate from the AAFB landfill. Calculations must be performed to determine the deflection experienced by the pipe according to the applied load. Pipe deflection should not exceed 5 percent [3]. One method for calculating the deflection of a pipe is known as the following modified Iowa formula [3].

$$\% \ (\Delta/D_p) = D * B * P * 100 \div [0.149 * (F / \Delta Y) + 0.061 * E'] \qquad (2)$$

D   Deflection lag factor
Range = 1.5 – 2.5: If the soil in the trench is not compacted, then the higher value of D should be used. If the soil in the trench is not compacted, then the lower value of D should be used. A value of 2 was used for AAFB.

B   Bedding Constant
Range = 0.08 – 0.1: Pipes embedded in gravel or sand. A value of 0.09 was used for AAFB.

D_p Diameter of the pipe (in). A value of 6.0 inches was used for AAFB

Δ Deflection

F   Modulus of elasticity of pipe material (psi)

E'   Modulus of soil reaction (psi)
Range = 100 – 400 for sandy soil and rounded gravel
A value of 200 was used for AAFB.

$F/\Delta Y$ Pipe Stiffness (psi); For landfill less than 20 m in height use the following for 6 inch diameter pipe, Schedule 80, approximately equal to 700. A value of 700 was used for AAFB.

P   Pressure on the pipe (psi).

The pressure (P) applied to the pipe is calculated by finding the mass of material placed on it. The thickness and density corresponding to the daily/intermediate cover, final cover, MSW and the maximum leachate head must be calculated. The density of the one-foot of drainage rock was considered negligible compared to these other factors. The first step was to calculate the density of the waste, soil and water.

The compaction density of the MSW in pounds per cubic yards was converted to pounds per cubic foot. The soil was assumed to have the same compaction density as the MSW. Based on a compaction density of 1,000 pounds per cubic yard the corresponding density would be 37 pounds per cubic foot. The water density was found by assuming a worst case, three-foot head on the liner system. Multiplying the three feet

by the water density of 62.4 pounds per cubic foot yielded the corresponding 187.2 pounds per cubic foot.

The thickness of the daily cover and final cover (SC) was calculated next. The height of the final cover was subtracted from the overall height of the landfill. Once this value of MSW height was found it was multiplied by the inverse of the waste to cover ratio. Finally the height of the final cover was added to this total. SC represents the total thickness of soil present above the pipe if one were to take a cross section of the fill.

Finally, the total pressure was calculated by multiplying the height of the soil, MSW and water by each corresponding density. This figure in pounds per square foot was converted into pounds per square inch and used as P in equation (2) above. Based on the modified Iowa formula presented above a calculation could be made to determine the quantity of stress placed on the leachate collection system pipe.

2.11 Risk Assessment

2.11.1 Air Pollution

In compliance with RCRA, subtitle D, the base Bioenvironmental Engineering flight monitors the perimeter of the landfill and all operations and maintenance buildings for methane levels. The regulation stipulates that methane concentrations must be 25 percent of the lower explosive limit in on-site structures. In addition, methane concentrations must be less than the lower explosive limit at the landfill site boundary. To date, these regulations have been met. Methane does not have an associated Time Weighted Average (TWA), however, it is classified as a simple asphyxiant [1]. The American Conference of Governmental Industrial Hygienists (ACGIH) defines a simple

asphyxiant as a chemical, when present in high concentrations in air, that will displace oxygen in a given volume [1].

2.11.2 Microbial Aersols Associated with Landfill Operations

A study was conducted to evaluate the risk associated with microbial aerosols generated during a typical day of landfill operations. This study concentrated on answering concerns over microbial aerosols generated from blowing dust on the landfill site. The study found the potential for human health risk from airborne mico-organisms should be less than those experienced from airborne microbes from sewage treatment plants [13]. Numerous studies have been conducted on high-risk personnel who work in and live around wastewater treatment plants and have been exposed to domestic wastewater. Few of these studies have been able to demonstrate significant health problems from microbial aerosols [13]. One study conducted found that vegetation growth around aeration tank at a wastewater treatment plant was sufficient to suppress aerosols [26].

2.11.3 Microbial Aerosols Associated with Composting Operations

In addition to public concerns over landfills there is an equal concern for composting facilities. Two separate reports were available on occupational hygiene on composting facilities. The most common pathogen of concern was the Aspergillus fumigatus. This fungus is most commonly known to cause allergy and hypersensitivity pneumonitis in susceptible populations. The most common complaint of workers is the odor, which is mainly caused by carboxylic acids [40]. Air samples were taken through

all phases of an open air composting process. Results showed "the concentrations of microbes were never so high as to constitute an acute health hazard from the occasional exposure" [40]. They did continue by saying that continuous exposure does increase the risk of illness.

The addition of wood chips, working with smaller windrows and increasing the turning frequency was found to reduce the odor emissions. The disadvantage to this was an increase in associated operating costs.

A separate study found "there is little reason for concern about the risk of potential infections from exposure to Aspergillus fumigatus among healthy individuals in either the general population or workforce exposed to composting bioaerosols" [26]. However, this study did warn that there will be a higher risk to individuals with suppressed immune systems and asthmatic health problems associated with any prolonged exposure to spores or fungus.

2.11.4 Leachate

According to many studies, bacteria and viruses are nearly non-existent in leachate. The potential for workers or community members swimming or drinking leachate is small. The leachate typically flows from the leachate collection system, to a treatment or hold tank, and then sent to the municipal wastewater treatment plant. The leachate effluent that flows through this system would have a lower pathogen count than the effluent leaving a wastewater treatment facility. It is suggested that the increased temperatures of a sanitary landfill and the antagonistic properties of leachate may exhibit significant adverse effects of the survival of pathogenic agents [26].

2.11.5 Ground Water

Water pollution posed by leaking leachate from the liner or collection system has the potential to migrate into and contaminate surface or ground water sources. This scenario is of greatest concern to the EPA when compared to all of the risks associated with a landfill since it poses the most risk to human health [9]. The USEPA "Subtitle D Risk Model" was developed to assess the impacts of non-hazardous waste landfills on groundwater sources [43]. The report was presented to congress in 1988 outlining the current status and associated risks of non-hazardous landfills. This report outlined the following findings based on the incidence of cancer to the exposed population:

A   60 percent of landfills pose less than a 1 in 10 billion risk of cancer incidence

B   6 percent of landfills pose 1 in 1 billion risk of cancer incidence

C   17 percent of landfills pose less than 1 in 1 million risk of cancer incidence

D   12 percent of landfills pose greater than 1 in 1 million but less than 1 in 100,000 risk of cancer incidence

E   5 percent of landfills pose greater than 1 in 100,000 but less than1 in 10,000 risk of cancer incidence

The EPA considers a risk of 1 in 10 billion risk of cancer incidence as zero risk. It is important to note that all of the landfill facilities included in the 60 percent category were located one or more miles from the groundwater source. The EPA established this one-mile cut-off as a "safe-distance" and the model was designed based on this precept.

The existing landfill was built on top of a closed landfill. The closed landfill operated from sometime after 1975 to 1998. Landfill operations occurred in this unlined, borrow pit throughout this time frame. No leachate collection system has ever been installed to collect leachate from the old landfill. Environmental samples taken from the

surrounding water monitoring wells have not indicated the presence of any constituents exceeding primary drinking water standards.

There is limestone bedrock between the bottom of the old landfill and the aquifer. The thickness of the limestone is between 285 and 385 feet. A study conducted by an independent agency calculated the following specifications for the limestone. The limestone had a hydraulic conductivity, hydraulic gradient and porosity of 13,000 feet per day, 0.00025, and 13.0 percent respectively. The average velocity through this layer is 25 feet per day. Theoretically, based on Darcy's law, it would take a water molecule between 11.5 to 15.5 days to traverse this distance.

2.11.6 Compliance Site Prioritization

The Air Force has tasked each command and installation to establish Hazardous Materials Management Process (HMMP) Teams. This team, led by Civil Engineering, will lead the compliance through pollution prevention implementation. The HMMP team evaluates and prioritizes compliance sites by analyzing compliance costs with operational and Environmental Safety and Health risks [2]. A four step process is used to assess each compliance site and subsequently assign an overall priority.

This four step process includes compliance cost rankings (step 1), risk assessment (step 2), compliance burden identification (step 3) and prioritization (step 4). Since a complete economic analysis of the landfill at AAFB was not performed a cost compliance ranking (step 1) could not be completed. Subsequently the compliance burden identification (step 3) and prioritization (step 4) could not be performed.

Using the information provided below in Table 2, a risk assessment (Step 2) will be performed in section 4 of this report and a score assigned based on the results of this study.

Table 2 Risk Assessment Matrix

ORM RISK ASSESSMENT MATRIX OF HAZARD CATEGORIES					
Probability Categories - A Severity Categories - B	Frequent	Likely	Occasional	Seldom	Unlikely
Catastrophic	1	2	6	8	9
Critical	3	5	7	10	15
Marginal	4	11	12	14	17
Negligible	13	16	18	19	20

A   Probability Category Definitions:
  (i)   Frequent:
        Qualitative Definition – Occurs often in the life of the system
        Quantitative Definition – Probability of occurrence is greater than one in ten
  (ii) Likely:
        Qualitative Definition – Occurs several times in the life of the system
        Quantitative Definition – Probability of occurrence is less than one in ten but greater than one in a hundred
  (iii) Occasional:
        Qualitative Definition – Will occur in the life of the system
        Quantitative Definition – Probability of occurrence is less than one in a hundred but greater than one in a thousand
  (iv) Seldom:
        Qualitative Definition – Unlikely, but could occur in the life of the system
        Quantitative Definition – Probability of occurrence is less than one in a thousand but more than one in a million
  (v)   Unlikely:
        Qualitative Definition – So unlikely you can assume it will not occur in the life of the system
        Quantitative Definition – Probability of occurrence is less than one in a million
B   Severity Category Definitions:
  (vi) Catastrophic – Complete mission failure, loss of system, loss exceeding $1 million, death, permanent total disability, or irreversible environmental damage that violates law or regulation.
  (vii) Critical – Major mission degradation, major system damage, loss exceeding $200,000 but less than $1 million, permanent partial disability, severe injury or occupational illness that may result in hospitalization of a least three personnel, or reversible environmental damage causing a violation of law or regulation.
  (viii) Marginal – Minor mission degradation, minor system damage, loss exceeding $10,000 but less than $200,000, injury or minor occupational illness resulting in a lost work day, or mitigable environmental damage where restoration activities can be accomplished without violation of law or regulation.
  (ix) Negligible – Less than minor mission degradation, minor system damage, loss exceeding $2,000 but less than $10,000, injury or occupational illness not resulting in a lost work day, or minimal environmental damage not violating law or regulation.
Source, adapted Figure A2.1., Attachment 2 [1]

During the risk assessment step a realistic worst case scenario is considered for the compliance site. In the case of AAFB, as described above, the potential for ground water pollution from leachate infiltration poses the greatest risk to the environment and

public health. According to the worst case calculations made during the construction of the AAFB landfill, leachate could potentially leak at the rate of 56.3 gallons per acre per day. The potential impact of polluting the aquifer would be significant when one considers this rate over six acres would be 338 gallons per day.

2.12 Leachate Monitoring

Leachate monitoring and analysis is important for two reasons. First, the information gained from the sample results will provide a basis for determining the phase of degradation the landfill is in. Second, it serves as a basis for determining a corresponding leachate treatment process. As described earlier there are four phases in the process of landfill degradation and each has associated level of constituents. An organization could allocate a large amount of resources toward leachate sampling due to the wide variety of constituents, which may or may not be present in the MSW. There is a consensus in the field of waste management as to which constituents should be considered in a comprehensive leachate sample plan. Typical concentrations of components found in new and old leachate are provided in Table 3. These constituents should be included in a routine leachate sample plan.

Table 3 Composition of Leachate from New and Stabilized Landfills

Constituent	Value, milli-grams per liter – A		
	New landfill (less than 2 years)		Mature landfill (greater than 10 years)
	Range - B	Typical - C	
BOD5 (5-day) Biological Oxygen Demand	2,000–30,000	10,000	100-200
TOC Total Organic Carbon	1,500-20,000	6,000	80-160
COD Chemical Oxygen Demand	3,000-60,000	18,000	100-500
TSS Total Suspended Solids	200-2,000	500	100-400
Organic Nitrogen	10-800	200	80-120
Ammonia Nitrogen	10-800	200	20-40
Nitrate	5-40	25	5-10
Total Phosphate	5-100	30	5-10
Ortho Phosphate	4-80	20	4-8
Alkalinity as CaCO3	1,000-10,000	3,000	200-1,000
PH	4.5-7.5	6	6.6-7.5
Total Hardness as CaCO3	300-10,000	3,000	200-1,000
Calcium	200-3,000	1,000	100-400
Magnesium	50-1,500	250	50-200
Potassium	200-1,000	300	50-400
Sodium	200-2,500	500	100-200
Chloride	200-3,000	500	100-400
Sulfate	50-1,000	300	20-50
Total Iron	50-1,200	60	20-200

A Except pH, which has no units

B Representative range of values. Higher maximum values have been reported in the literature for some of the constituents.

C Typical values for new landfills will vary with the metabolic state of the landfill.

Source, adapted Table 11-13, [39]

In addition to the above mentioned items the following constituents should be sampled for as well.

A   Organic Chemicals: Phenols, volatile acids, tannins, lignins, ether soluble, methylene blue acitve substances, and chlorinated hydrocarbons.

B   Inorganic Compounds: Suspended solids (SS), Total Dissolved Solids (TDS), Volatile Suspended Solids (VSS), Volatile Dissolved Solids (VDS), Phosphate, Nitrite as N, Arsenic, Cyanide, Fluoride, Selenium, and Heavy metals to include Lead, Copper, Nickel, Chromium, zinc, Cadmium, Iron, Manganese, Mercury, Barium, Silver.

C   Biological and Physical: Oxidation-reduction potential, conductivity, color, turbidity, temperature, coliform bacteria to include total, fecal, fecal streptococci, and a standard plate count

2.13 Landfill Mining

Once the landfill has stabilized, verified by sample results identified in 2.11, it will be comprised of a significant amount of fine cover soil, decomposed material and inert material. A growing practice is emerging in the field of waste management to mine old landfills. The cap of the landfill is removed and the underlying material is removed. This material is then processed to separate and recover portions of the material. The main goal of this procedure is to reclaim landfill space and reduce the risk of leachate contamination [28]. A significant advantage to this practice is the reduction of MSW requiring subsequent re-disposal.

The primary benefit to landfill mining is a significant reduction in the number of years required for post care. Once the landfill is mined the source of potential contamination is eliminated. The landfill managers would merely need to continue sampling the groundwater monitoring wells as prescribed by the local EPA agency. If a contaminant were found, remediation efforts would be initiated. Although contamination from a landfill is not thought of in the same manner as a fuel spill, it would be managed using the same technology and basic remediation principles.

3. MODEL FORMULATION

3.1 Development of Landfill Extension Modeling (LEM) Program

The following sections detail the construction of the LEM program used in conducting the data analysis. Subsequent sections below will describe input data for the model relative to initial landfill operating parameters, alternate operating parameters, recycling program specifications and information provided on alternative methods to extend the landfill's useful life. The design of this LEM program was revolutionary in the management of solid waste disposal. The program was written using MS Excel. The benefits to the use of this computer platform include ease of use, compatibility with current computer systems and no requirement to purchase supporting software. The model is based on the existing landfill and MSW management at Andersen AFB, Guam; however, it may be used on any landfill operation. A detailed instruction manual is provided in Appendix 2. The user should follow this instruction manual to gain a more thorough understanding of the program.

3.2 Initial Analysis Page

The LEM may be used at any time in the operating life of the landfill. The initial analysis page requires input based on the current operating specifications for the landfill, see Appendix 1, Tables 5.a – 6

The parameters for the landfill construction include the available landfill area, length to width ratio, average depth of area and side slope ratio. Available landfill area, footprint, does not include the anchor area used to secure the landfill HDPE liner. Only information directly related to available volume is required. The program supports various footprint dimensions and calculates the corresponding length to width measurements. Landfill elevation may be input up to a maximum of 70 feet, however AAFB is limited to 45 feet in the final construction height. A final cover depth was assumed at 8 feet for this landfill. The maximum number of lifts, height above ground with no cap and height above ground with a cap is shown in the output parameter section.

Andersen AFB has an available area of 6 acres with four equal sides. The length to width ratio of 1:1 represents this shape. The average depth was approximated at four feet. This is based on a six-foot depth on the West Side and a three-foot depth on the East Side of the fill area. The side slope of the fill was constructed with a slope ratio of 3:1. AAFB landfill operational instructions specify filling the landfill to the top of the berm, which corresponds to the surrounding ground level. This model is based on this premise and considers the first level built up from the ground level as the second lift.

Typical lift heights range from eight to ten feet. Nine-foot heights will be used for lifts two through four and an eight-foot height will be used for the fifth lift. This configuration was arbitrary and with a 44.5 foot final height meets the 45-foot height requirement. When entering lift information, the operator should continually monitor the height above ground with cap output, see Table 7-C, to ensure the desired height input is not exceeded. To maximize the volume afforded by the input dimensions, this distance should be within one foot of the desired maximum elevation. Once all lift

information balances an OK will be indicated in the corresponding lift input section. If the information in the lift section is out of range or not needed a N/A will be indicated.

Intermediate cover is typically used between lifts. In addition to the same benefits derived from the use of daily cover provides the equipment a more stable surface on which to operate. This layer is typically 0.5 feet in depth and is removed prior to placement of the next lift. The model assumes a loss of 0.5 feet between lifts as a worst case calculation. A terrace is used when a landfill height exceeds fifty feet. For safety purposes it provides equipment operators an acceptable base to work from. This input is not necessary for AAFB. The program will calculate when the terrace width is required and subsequent volumes will be adjusted accordingly. The volume of intermediate cover is calculated on the initial calculation sheet with the total reported as baseline landfill life in the output parameter section.

A volume is calculated for each lift, see appendix 1 for calculation equations. A middle area is calculated and multiplied by the lift height. Two lengths and two width areas are calculated by deriving the slope width from the slope ratio information. Each lift is calculated separately by subtracting the slope width from the previous lift. The overall available baseline volume is calculated on the initial calculation sheet with the total reported as baseline landfill life in the output parameter section. A baseline time to fill calculation is made based on the daily input, compaction density and available volume. This calculated value is reported as the baseline time to fill.

The daily quantity of MSW requiring landfill was derived from daily reported values collected over a one-year period from 1 January 1998 to 28 February 1999. Based on this information, the mean reported monthly MSW totals from housing and industrial collection was 26,218 pounds per day (13.1 tons per day). The standard deviation was 5,171 pounds per day (2.6 tons per day). Since the base population was

not available a pounds per capita per day figure was not calculated. The Phase I Report on Integrated Solid Waste Management Plan for the Island of Guam, found the base waste generation per capita as 4.5 pounds per person per day. This along with a base population of 8,950 was used to verify the accuracy of the model. A value of 13.0 tons per day was used to perform the analysis of this study. The model will use the landfill input information if it is entered on the sheet. The default uses the 8,950 population and 4.5 pounds per person per day. An assumption was made that there will not be an annual population growth. If a mission change for the base were anticipated the new loading information sheet would be used to account for this growth.

The base does not currently assess a tipping fee for incoming waste. For this analysis a tipping fee was calculated based on the approximate cost of the landfill construction divided by the amount of MSW predicted to be placed. A tipping fee of $90 per ton is the approximate cost to dump (tip) at this facility. This figure is on the high side of the national average, but reasonable considering the location of the site.

Three blocks are provided to assess the initial status of landfill operations. Soil is currently used as a daily cover method. This equates to a 10 to 20 percent loss of available landfill volume. A figure of 15 percent will be used to calculate the loss associated with current operations. The landfill uses Caterpillar D5 tractors to move and compact the landfill. Typical compaction achievable by this type of equipment ranges from 900 to 1,100 pounds per cubic yard. A value of 1,000 pounds per cubic yard will be used to reflect current operations. The landfill does not shred MSW prior to placement in the landfill. A value of 0.0 percent is used to represent current landfill operations.

Landfill managers may input the amount of landfill currently filled. Enter the value for the number of lifts completed and, if applicable, the percentage of the current working lift filled. The corresponding percentage of landfill filled will be displayed in the output

parameter section of the page. If the landfill is partially filled an adjusted volume and time to fill will be calculated. A comparison will be made to the baseline life and an elapsed time will be reported in the output parameter section.

As mentioned earlier, 40 CFR 60, requires gas monitoring from landfills using the New Source Performance Standards (NSPS). If the landfill exceeds the 55 tons per year Non-Methane Organic Compounds (NMOCs) emission standards, landfill managers are required to perform Tier 2 testing. Tier 2 testing requires the landfill manager to sample the site for the actual NMOC concentration. The model uses the EPA default of 4,000 parts per million to perform the Tier 1, baseline calculations. Results from the sampling will be entered on this page in the NMOC concentration block.

If the landfill exceeds 55 tons per year based on these sample results, Tier 3 testing will be required. Tier 3 requires the operator to determine the specific methane generation constant K for the landfill. The results from this testing will be input in the Methane generation block. The model uses the EPA default value of 0.015 liters per year when no value is entered.

The Scholl Canyon model is used in this program to find the NMOC emissions estimates. This equation requires input reflecting the number of years since the landfill was closed. The years since closure time, in years, should be input in the "since closure" block. The program will default to zero if the landfill is in operation unless there is a value entered here.

At the time of the site visit the landfill volume was not completely utilized. After a review of procedures, operations were changed and are currently reflected in this model. The immediate savings doubled the life of the landfill from 10 years to 20 years. The associated cost of this volume saving to complete the first lift, considering an approximate $90 dollar per ton tipping fee was be nearly $250,000. The landfill has

been open since August 1998. The existing soil cover will be removed as new MSW is placed. The assumption is made in this model that the current landfill has over 95 percent space remaining.

3.3 Base Recycling Program

3.3.1 Waste Stream Analysis

AAFB's MSW stream was analyzed in 1993, see Appendix 1, Table 23. The data input for this model were based on a previous study conducted on Kadena AFB. These results were consistent with the national breakout of MSW. The program provides the operator an avenue to change these values. This is not recommended, however, unless a current study is performed to analyze the waste stream.

If the recycle rates for the categories are known, they may be entered on this page. The daily production of each MSW stream was broken down on this page based on the amount recycled in each category. The adjusted ton per day is the amount of MSW placed in the landfill. This number is an output parameter on the initial analysis page. The overall base recycle program efficiency is calculated on this page and is shown as an output parameter on the initial analysis page.

Currently AAFB is recycling/diverting aluminum, glass, cardboard, paper/magazines, scrap metal, pallets/crates, construction and demolition debris, and yard waste. It is assumed there is 100 percent diversion for the pallets/crates, construction/demolition debris and yard waste.

The current selling price per ton of recyclable material may be entered in the corresponding block on this page. This price will be used in the base recycling program

cost analysis table to calculate an overall recyclable material balance. Based on AAFB information the market is currently open to aluminum, cardboard and paper/magazines.

An algorithm was provided for the operator to calculate the recycle rate of any material in question. If the amount of material recycled in pounds per month is known it may be entered here. This calculator converts the daily generation of each category, tons per day, into pounds per month. The recycle efficiency output for that material may then be input into the corresponding recycle rate block.

3.3.2 Recycling Cost Analysis

A cost analysis was performed on cardboard, wood pallets, glass, aluminum, scrap metal, paper/magazines, yard waste, construction and demolition debris and composting of food wastes, see Appendix 1, Table 24. This analysis is based on the premise that the money invested in the overall recycle program is subdivided into each of the above categories. When the operator enters the percentage of time invested in a specific area, the program will allocate that percentage of the invested money toward that program. Monetary investments include operations, maintenance and equipment. If all of these functions are performed by a contract, the overall annual contract cost may be entered in the expansion block under operations. All other expenditure categories covered by contract services would be blank.

The income generated by a recycling program is expressed not only in terms of the money gained from the sale of the item, but also in the volume of the landfill saved. In each category the quantity of material diverted from the landfill is calculated in tons per day. This quantity is multiplied by the corresponding tipping fee assessed for the landfill. The total generation is then calculated by the addition of these two amounts.

The individual analysis results are posted on this page and the overall balance is presented on the summary and waste stream analysis pages.

3.4 Initial Calculation Page

This page is used to perform all of the initial analysis calculations to determine landfill life, available landfill volumes and corresponding cumulative MSW, see Appendix 1, Tables 7 - 11. These results are based on the input provided by the operator. This page is comprised of five tables. These tables include lift analysis, fill and cover calculations, leachate pipe stress calculations, time to fill calculations and MSW generation calculations. All of the supporting equations are presented with the applicable Table in Appendix 1.

3.5 New Loading Page

The new loading page is used to model future landfill capacities and life based on proposed changes to base population, growth, waste generation rate, intermediate cover, tipping fee, base MSW input and community MSW input, see Appendix 1, Tables 12.a – 13. The base mission may change in the future resulting in an increase or decrease in MSW generation. New populations may be written in or an equivalent annual population growth or decline may be used. Many cities use a three percent population growth to forecast future landfill requirements. A military installation would not fall under this guideline as the base population is driven by mission requirements.

As the landfill is constructed various lift heights and intermediate covers may be measured based on equipment and operations constraints. This new information may

be used in the corresponding lift and intermediate cover blocks. A new tipping fee will be calculated and displayed on the summary page based on these new procedures. This tipping fee is calculated using the same logic as defined above. If no changes to the landfill are made, this tipping fee will equal the initial tipping fee.

Information pertaining to the community population, waste generation rate and growth will be input according to the contract option on the option input page. This option will be discussed in more detail in the option input section. The landfill compaction, corresponding volume loss due to daily cover and shredding options will also be addressed in the option input section. When the landfill compaction exceeds the typical range of landfill compaction using a Cat D-5 tractor, 900 to 1,100 pounds per cubic yard, the operator is reminded to input a 3:1 slope. As discussed earlier, a 3:1 slope is associated with the increased capabilities of using an MSW compactor.

The new loading output parameter section is designed the same as the corresponding initial analysis output parameters. The initial landfill life and time to fill numbers are derived on the initial analysis calculation page. The new loading landfill capacity and time to fill figures are derived on the new loading calculation page. The new time to fill based on the proposed changes will be presented in this section. A calculation is made to determine the difference between the new time and the baseline time. This change will be reflected as a loss or gain.

3.6 New Base and Community Recycling Programs

The new base recycling program page was installed to provide the operator an avenue to investigate changes to the recycling program, see Appendix 1, Tables 23 - 24. Changes may be made to any of the categories in question. A new cost analysis will be

performed and a new landfill life will be realized based on the proposed change. This is instrumental in future recycle planning strategies.

The community recycling page was installed to investigate the community MSW stream. If the ultimate goal of the program is contract support, one avenue is community collection. A detailed assessment of the waste stream should be performed and data entered on this page. Based on the geographic location of this installation, an assumption was made the community waste stream was similar to the base. Based on these similarities the cost analysis page was configured to model the base program.

The composting option was included on the new base and community recycling program sheet. A composting system would target the organic constituents in the MSW. The largest contributor of currently landfilled waste is food waste. An earlier study estimated that nearly 25 percent reduction could be realized by composting. Both of these sheets are configured to automatically reduce the food waste stream by up to 25 percent based on the selection of the composting alternative.

3.7 New Loading Calculation Page

This page is used to perform all of the new loading calculations to determine the new landfill life, available landfill volumes and corresponding cumulative MSW, see Appendix 1, Tables 14 - 18. These results are based on the input provided by the operator. This page is comprised of five tables. These tables include lift analysis, fill and cover calculations, leachate pipe stress calculations, time to fill calculations and MSW generation calculations. The MSW generation table is functionally different from the initial MSW generation table presented earlier. In order to insure greater accuracy of landfill volume calculations the elapsed time is used to set all corresponding year values

to zero. The model will only use information related to the remaining life of the fill. All of the supporting equations are presented with the applicable Table in Appendix 1.

3.8 Option Input Page

Alternative methods to extending the life of an existing landfill are made on this page, see Appendix 1, Tables 19 - 21. Alternative daily cover, shredding, compaction and composting are the most well documented methods used for increasing the capabilities of a landfill. Each of these options are presented on this page and can be selected individually or in any combination by clicking on the appropriate box. The corresponding inputs required for a complete cost analysis of the option(s) are addressed.

The capital cost, miscellaneous support equipment, system operation/maintenance costs and associated life of the applicable units are required. Typical costs associated with these systems have been entered on the page, but landfill managers must input current information based on the market. Various companies specialize in manufacturing the equipment specified in this paper. A product review should be performed to ensure current capital, operational and maintenance pricing information is available. The option variable blocks for each alternative has an associated input. These input parameters are based on the literature review reported earlier.

3.8.1 Alternative Daily Cover (ADC)

The alternative daily cover (ADC) option considers using a tarp system for 330 days per year and soil for 35 days per year. This assumption was based on AAFB using heavy weight tarps braided with steel cables. The time was arbitrarily chosen based on the climate conditions of Guam. It was assumed that no more than 35 days per year would have wind speeds greater than 30 miles per hour. Since the typical range for volume lost to soil ranges from 10 to 20 percent a baseline figure of 15 percent was used, see initial input page. If 15 percent loss were expected using soil 365 days per year a one percent loss of volume would be expected for 35 days per year operation. This variable is used in the new loading calculation page and a new landfill life is calculated based on the landfill volume saved. Given a tipping fee, the monetary equivalent of this volume was also calculated.

A typical capital cost for a tarp system is $175,000. The miscellaneous cost includes buying two tarps at $3,000 every 3 years. The tarp system can mount onto the existing Cat D-5. An annual operation and maintenance cost was assumed to be $2,000.

Published findings indicate approximately three hours per day are used to place and remove a soil daily cover. This information based on a 365 day per year was input in the initial operation section. Using a tarp system, approximately 45 minutes per day are used to place and remove the top cover. Due to the climate of Guam, this system would be used approximately 330 days per year. Soil would be used for the remaining 35 days in the year. This information was input in the appropriate new operations and new operations sections.

3.8.2 Shredder

Capital costs associated with purchasing a Flail hammermill shredder were approximately $200,000. To replace blades on a regular basis, $2,000 was assumed for every 5 years of life. Since shredding is not currently used at the landfill there are no associated initial operations costs. Based on the 13.1 tons per day MSW input shredder operations would not exceed 4 hours. It was assumed one person could operate the machine. Shredding would result in up to a 15 percent increase in available landfill space. In addition to the other benefits of vector control and increased compaction this number may be conservative to the overall benefit to the landfill operations.

3.8.3 Compactor

Capital costs associated with purchasing a MSW compactor were approximately $350,000. One source reported hourly operating costs of $80 to $120 per hour. No miscellaneous parts would be required on a regular basis. All other costs would fall under the operations and maintenance cost assumed to be $3,000 per year. The typical compaction realized using a compactor ranges from 1,200 to 1,700 pounds per cubic yard. A figure of 1,500 pounds per cubic yard was used in these calculations. The initial operation and new operation costs would be nearly the same.

3.8.4 Compost

A study would need to be performed to determine the capital costs of establishing a compost system. AAFB has most of the equipment to manage the compost

operations. A capital cost of $75,000 was assumed to purchase incidental equipment with an annual operations and maintenance cost of $2,000. Based on a previous study a landfill savings estimate was estimated to be equal to a 25 percent diversion in the food waste category. The operations would involve one person working three hours per day to manage the compost material.

3.8.5 Expansion Slot

An expansion slot was included for the operator to experiment with other alternatives to extending the useful life of the landfill. All of the slots are functional and operate in the same manner as the other four options.

3.8.6 Contracting

An additional alternative of contracting was investigated. The operator has many choices when it comes to contracting. Once the contract option is selected any or all of the alternatives may be selected. This would be useful to identify the costs of contracting out these options. The operator may also investigate accepting community waste. The applicable information pertaining to community population, waste generation per capita and population growth would be entered here. This information is subsequently used in the new loading calculations. A tipping fee may be entered to investigate generating community revenue to finance the contracting operation.

3.8.7 Output Parameters

The cost analysis page performs all of the calculations needed to adequately analyze the selected alternative(s). The figures derived from these calculations are input on the option input page to eliminate the need to change pages when a new option is selected. This sheet does not take the monetary equivalent of recycling into account. The summary page will adequately address the complete landfill analysis to include recycling efforts.

3.9 Cost Analysis Page

This sheet is used to perform a cost analysis on the alternative(s) selected on the option input page, see Appendix 1, Table 22. The baseline life and weight of the landfill are compared to the new life and weight realized by implementation of the alternative(s). The total capital costs of the alternative(s) were multiplied by the average life of the equipment and divided by this new calculated life. Likewise the miscellaneous costs are annualized in the same manner. The associated numbers of equipment and miscellaneous equipment required for purchase over the new life of the landfill are calculated by dividing the new life of the landfill by the average corresponding unit lives.

An initial analysis was performed on the program to determine a programming code to calculate the depreciation of all factors over the landfill life. A set landfill configuration was input on the initial analysis page with 100 percent life remaining on the landfill. Values were obtained for each category and manually loaded in the cost analysis table. The landfill life was then adjusted for 95 percent life remaining on the landfill. Values were again obtained for each category and manually loaded in the cost

analysis table. This procedure was repeated until 100 percent of the landfill was filled. The correction factors derived from these landfill specifications were recorded on the program regression equation page. The landfill configuration was altered for various scenarios and the above steps were repeated. In all test runs, the correction factors were nearly identical. Plotting these correction factors against the percentage of landfill filled produced the Program Regression Equation graph. A sixth order regression equation was generated from this graph and used in the program. This equation makes it possible to perform a cost analysis at any stage of a landfill life.

The total expenditures considered in this program were from the associated salaries and equipment costs. The monetary gain was associated with the net gain in landfill volume, compaction density and corresponding tipping fee. As stated earlier, the recycling costs are not considered in this portion of the cost analysis. The summary page will provide the overall final analysis.

A value will be derived based on this corresponding balance. This value will indicate the point in the landfill life where the chosen alternative(s) are no longer feasible. The program only calculates information in increments of five percent. No greater accuracy is required to perform this type of cost analysis.

3.10 Regression Analysis Graph

A computer-generated graph was provided in the LEM program to show the analysis of the alternative(s) selected by the landfill manager, see Figure 2. Alternative Daily Cover (ADC) was chosen to illustrate this function. Based on the ADC information provided an economic analysis was performed and an annual operating cost was calculated. Correspondingly, a net gain of landfill life was calculated based on using

ADC. The landfill was losing an estimated 15 percent landfill space to soil placed as daily cover. Using the ADC alternative an anticipated landfill space loss of one percent was calculated based on the information shown in section 3.4 above. The end result was an approximate net gain of 14 percent additional landfill space to be realized by the alternative. As described above this equates to an annual monetary gain when one considers the associated tipping fee and MSW compaction density.

An annual balance was derived based on the corresponding annual operating costs and annual revenue realized by the increased landfill space. A separate calculation was made for each five percent increment of the landfill life remaining. Subsequently, this information was plotted in the graph shown in Figure 2. Using the ADC example, the feasibility point for this alternative was calculated at approximately 73 percent. Based on these results, the ADC alternative would no longer be feasible after approximately 70 percent of the landfill was completed.

According to calculations made in this example the landfill manager could anticipate a three-year landfill life extension using ADC. This was the equivalent of approximately 22 years. Based on the derived 70 percent of landfill life completed, this would equate to approximately 16 years. In other words the landfill manager could theoretically incorporate ADC into facility operations and realize a net gain over the first 16 years of the landfill life. Incorporating ADC any time after the sixteenth year would likely result in an annual loss to the landfill facility.

3.11 Summary Page

A complete synopsis of the information presented above is shown in one section of the LEM program, see Appendix 1, Table 25. This section provides information on

which alternatives were selected, operational and maintenance expenses, revenue realized by recycling program, and landfill life extension. A detailed status assessment is provided on the new source performance standards for NMOC production. Instructions are recommended to the operator based on the inputs on the initial analysis page and the results of the Scholl Canyon model. This function is important when considering alternatives to extend the life of a landfill because the facility is placing addition MSW in the landfill. For example, if the 55 ton per year NMOC emission standards are exceeded the selected alternatives may no longer be cost effective when one considers the additional costs of air sampling and possible emission control equipment mandated by new source performance standards. Costs associated with the compliance of this standard are not considered as part of the annual balance in this version of the LEM program.

The results of the modified Iowa formula, as outlined above, are presented on this page. In addition to the concerns of exceeding the emission standards a landfill manager must be concerned with leachate collection system piping. Placing more MSW in the landfill subsequently results in an increase weight on the leachate collection system and subsequent increase of stress on the piping. If the percentage of stress on the pipes exceeds 5.0 percent a message will be displayed to reduce the compaction density on the fill or lower the lift heights. Any combination of these two solutions may decrease the weight of MSW placed in the fill and subsequently reduce the stress on the pipe system.

Although not covered in detail in this report, the LEM program has the capability to perform a complete analysis of the community recycling program and MSW waste stream. An annual monetary balance is displayed on this page to indicate the overall gain or loss for the recycling program. The annual recycling balance is based on the

annual cost to operate the recycle facility and the annual revenue based on sale of recyclable material as well as the gain in landfill space. Using the LEM program, a landfill manager can analyze current and proposed recycling plans for the community and MSW waste streams. It is important to relate the recycling program to landfill operations due to the possible corresponding increase in revenue from saving of landfill space. The overall recycling efficiency of both the current and proposed programs are then provided on this page.

3.12 Incinerator Analysis

The capital and operating costs of incinerators are substantial. Based on the information obtained during the literature review, the capital cost of the facility would be approximately $851,500 based on a 13 ton per day facility. The operating costs associated with this facility would be $191,100 per day. Given a power generation of 22,283 kilo-watt hours per day and a revenue of 5 cents per kilo-watt hour, a daily generation of merely $1,200 per day are realized. Combined with the approximated $90 per ton tip fee, revenue would only be $2,300 per day.

3.13 Leachate Recirculation

The initial capital costs for installation of a leachate recirculation system would be approximately $43,000. Based on a proposed saving of $2,500 per acre per year, this system would pay for itself within 3 years. When one considers both the projected $2,500 per month operations/maintenance fee and the reduction in time required for the landfill to reach stabilization, this system has a solid return on investment potential.

4. RISK ASSESSMENT SUMMARY

4.1 Air Pollution

Based on the results of air samples conducted to date and the worst case calculations for NMOC's the potential for occupational or public illness from related air pollution is minimal. Air monitoring should be continued to insure worker safety from the potential explosion and simple asphyxiant hazards associated with methane gas.

4.2 Microbial Aerosols Associated with Landfill Operations and Composting

The risks associated with microbial aerosols are minimal. According to published studies identified in the literature review section there is minimal potential for occupational or public illness due to microbial aerosols. There is a thick growth of vegetation surrounding the landfill site. This will minimize wide dispersion of dust from the site, further decreasing the potential for the spread of microbial aerosols.

4.3 Groundwater

A worst case scenario was considered for this landfill. The landfill is in close proximity to the water table and the limestone boundary does not offer a substantial buffer. A zero risk assessment for this landfill is impossible to assign since there is a potential for considerable leakage. A conservative risk assessment would put the landfill

in the worst five percent. According to the information in 2.11.5 the potential risk of cancer incidence due to groundwater contamination ranges from greater than 1 in 100,000 to less than 1 in 10,000.

The old landfill was capped during the new landfill construction. Since the old landfill was used until it was capped an assumption is made that it had not completely reached stabilization. Leachate production will occur, except at a slower rate and is not recovered in a leachate collection system. There is still a potential for ground water contamination from this site, especially when one considers a worst case scenario of 338 gallons per day of leachate leakage through the liner system of the new landfill. To date, water samples taken from the ground water monitoring wells have shown there are no constituents exceeding the primary drinking water standards. Sampling should continue assess changes to the levels of constituents monitored.

4.4 Compliance Site Prioritization

In accordance with Table 2, as introduced in section 2.11.6 above, a risk assessment (step 2) was made concerning the potential for ground water contamination. An overall risk assessment matrix score of "7" was derived based on the following analysis.

Probability Category: This category was assessed a worst case "Occasional" rating based on the close proximity to the aquifer and unlined lower landfill. As described in 4.3 above, the EPA stated the potential risk of cancer incidence due to groundwater contamination ranges from greater than 1 in 100,000 to less than 1 in 10,000. This range is covered in the "Seldom" and "Occasional" quantitative definitions.

A worst case assumption was made and the "Occasional" rating was selected. The qualitative definition states the worst case scenario will occur in the life of the system.

Severity Category: This category was assessed a "Critical" rating due to the potential costs for remediation to exceed $200,000 if a groundwater contamination incidence were to occur. Reversible environmental damage would also result if a groundwater contamination were to occur resulting in violation of the Clean Water Act.

5. RESULTS AND DISCUSSION

The following section is a discussion of the outputs provided by the model. Every combination of the proposed alternatives was analyzed. A regression equation was presented for each alternative. This regression equation may be used in lieu of the model to predict the point in the landfill life where the alternative(s) are no longer feasible. The only variable that will change in each analysis is the alternative selected. The other variables may be found in section 3 or in Appendix 1. One contract option evaluating the outsourcing of all alternatives was considered.

The baseline calculations indicate the landfill volume is currently 176,899 cubic yards and the time to fill based on a 1,000 pounds per cubic yard compaction density is 18 years 6 months. The equivalent pipe stress on the leachate collection system is 1.8 percent, which is within the acceptable range of 5.0 percent. The regression equation can be used to find the corresponding alternative balance, Y, by solving for the percentage of life remaining in the landfill, X. The final balance shown in the analysis below will not reflect recycling efforts. The recycling efforts as defined in this model show an annual gain and would not negatively effects these results. The following analysis is ranked in descending order by years of new life attainable by the landfill, see Table 4. In each case, information is also provided to indicate at what point in the landfill life the alternative(s) are no longer feasible. A more comprehensive analysis is also presented on each alternative and includes the corresponding regression equation.

Table 4 Summary of Alternative(s) Based on New Life Extension

Alternative(s)	New Life (Years)	Not feasible with _ % life remaining – A
ADC, Shredder, Compactor, Compost	48.4	10
ADC, Shredder, Compactor	43.4	10
Shredder, Compactor, Compost	42.7	10
ADC, Compactor, Compost	42.3	10
Shredder, Compactor	38.1	10
ADC, Compactor	37.8	10
Compactor, Compost	36.5	10
Compactor	32.4	5
ADC, Shredder	24.8	20
Shredder, Compost	24.4	35
ADC, Compost	24.2	15
Shredder	21.8	30
ADC	21.6	15
Compost	20.9	45
Contract: ADC, Shredder, Compactor, Compost	30.9	5

A This column shows at what point in the landfill life the alternative(s) are no longer feasible. For example, the first analysis presented in the table would no longer be feasible with more than 90 percent of the landfill filled (not feasible with 10% life remaining). These calculations are only valid for the data entered during the analysis of this report. All supporting data input is documented in section 3 and Appendix 1. Based on the inputs provided to analyze these alternatives the following list shows the percentage of landfill life remaining in terms of approximate years. 5% ≅ 1 yr; 10% ≅ 2 yrs; 15% ≅ 3 yrs; 20% ≅ 3.5 yrs; 30% ≅ 5.5 yrs; 35% ≅ 6.5 yrs; 45% ≅ 8.5 yrs;

5.1 Alternative Daily Cover, Shredder, Compactor and Compost

New Life (years) 48.4

Life was extended (years)..29.9

Not feasible with _ (percent life remaining) 10

Annual balance (dollars) 140,355

Pipe integrity (percent) 2.3

Regression equation:

$y = -4,890,077.9x4 + 7,468,996.5x3 - 3,527,754.2x2 + 529,816.8x + 125,137.5$

$R^2 = 0.916$

5.2 Alternative Daily Cover, Shredder and Compactor

New Life (years) 43.4

Life was extended (years)............................24.9

Not feasible with _ (percent life remaining) 10

Annual balance (dollars).......................................168,077

Pipe integrity (percent) 2.3

Regression equation:

$y = -4,938,035.1x4 + 7,613,421.0x3 - 3,697,216.8x2 + 593,493.4x + 153,115.0$

$R^2 = 0.952$

5.3 Shredder, Compactor and Compost

New Life (years) 42.7

Life was extended (years)............................24.2

Not feasible with _ (percent life remaining) 10

Annual balance (dollars).......................................117,038

Pipe integrity (percent) 2.3

Regression equation:

$y = -3,523,735.9x4 + 5,351,598.3x3 - 2,560,385.0x2 + 406,608.3x + 106,469.7$

$R^2 = 0.965$

5.4 Alternative Daily Cover, Compactor and Compost

New Life (years) 42.3

Life was extended (years)..23.8

Not feasible with _ (percent life remaining) 10

Annual balance (dollars)...155,259

Pipe integrity (percent) 1.9

Regression equation:

$y = -3,435,148.5x^4 + 5,244,565.4x^3 - 2,525,196.9x^2 + 404,273.2x + 144,995.8$

$R^2 = 0.960$

5.5 Shredder and Compactor

New Life (years) 38.1

Life was extended (years)..19.6

Not feasible with _ (percent life remaining) 10

Annual balance (dollars)...142,219

Pipe integrity (percent) 2.3

Regression equation:

$y = -3,372,956.2x^4 + 5,124,607.4x^3 - 2,452,602.2x^2 + 379,929.5x + 139541.2$

$R^2 = 0.956$

5.6 Alternative Daily Cover and Compactor

New Life (years) 37.8

Life was extended (years)..19.3

Not feasible with _ (percent life remaining) 10

Annual balance (dollars)...178,792

Pipe integrity (percent) 1.9

Regression equation:

$$y = -3,037,999.9x4 + 4,570,124.9x3 - 2,162,953.6x2 + 330,625.7x + 176,680.2$$

$R^2 = 0.954$

5.7 Compactor and Compost

New Life (years) 36.5

Life was extended (years)..18.0

Not feasible with _ (percent life remaining) 10

Annual balance (dollars)...141,503

Pipe integrity (percent) 2.3

Regression equation:

$$y = -1,997,638.2x4 + 2,797,598.8x3 - 1,186,697.9x2 + 14,3374.0x + 133,432.7$$

$R^2 = 0.948$

5.8 Compactor

New Life (years) 32.4

Life was extended (years)...13.9

Not feasible with _ (percent life remaining) 5

Annual balance (dollars)...158,413

Pipe integrity (percent) 2.3

Regression equation:

$y = -1,370,842.5x4 + 1,795,252.7x3 - 715,245.8x2 + 84,673.8x + 155,521.5$

$R^2 = 0.977$

5.9 Alternative Daily Cover and Shredder

New Life (years) 24.8

Life was extended (years)... 6.3

Not feasible with _ (percent life remaining) 20

Annual balance (dollars)...58,363

Pipe integrity (percent) 1.8

Regression equation:

$y = -5,358,673.6x4 + 8,436,291.0x3 - 4,290,095.1x2 + 736,501.1x + 38,528.6$

$R^2 = 0.945$

5.10 Shredder and Compost

New Life (years) 24.4

Life was extended (years)... 5.9

Not feasible with _ (percent life remaining) 35

Annual balance (dollars)..6,156

Pipe integrity (percent) 1.8

Regression equation:

$y = -2E+07x^6 + 5E+07x^5 - 5E+07x^4 + 2E+07x^3 - 4E+06x^2 + 363,448x + 2988.1$

$R^2 = 0.9937$

5.11 Alternative Daily Cover and Compost

New Life (years) 24.2

Life was extended (years)... 5.7

Not feasible with _ (percent life remaining) 15

Annual balance (dollars)...42,503

Pipe integrity (percent) 1.8

Regression equation:

$y = -3,545,475.5x^4 + 5,651,851.8x^3 - 2,916,718.3x^2 + 504,901.4x + 25,484.7$

$R^2 = 0.950$

5.12 Shredder

New Life (years) 21.8

Life was extended (years)... 3.3

Not feasible with _ (percent life remaining) 30

Annual balance (dollars)...27,714

Pipe integrity (percent) 1.8

Regression equation:

$y = -2,549,925.6x4 + 3,872,657.5x3 - 1,866,807.5x2 + 276,124.4x + 20,327.4$

$R^2 = 0.963$

5.13 Alternative Daily Cover

New Life (years) .....:..21.6

Life was extended (years)... 3.1

Not feasible with _ (percent life remaining) 15

Annual balance (dollars)...60,201

Pipe integrity (percent) 1.8

Regression equation:

$y = -2,037,127.2x4 + 3,091,818.4x3 - 1,495,511.0x2 + 221,841.6x + 54,011.8$

$R^2 = 0.961$

5.14 Compost

New Life (years) 20.9

Life was extended (years)... 2.4

Not feasible with _ (percent life remaining) 45

Annual balance (dollars)...687

Pipe integrity (percent) 1.8

Regression equation:

$$y = -312,658x5 + 628,732x4 - 445,829x3 + 127,934x2 - 13,321x + 875.7$$

$$R^2 = 0.9854$$

5.15 Contract: Alternative Daily Cover, Shredder, Compactor and Compost

New Life (years) 30.9

Life was extended (years)..12.4

Not feasible with _ (percent life remaining) 5

Annual balance (dollars).......................................271,239

Pipe integrity (percent) 2.3

Regression equation: N/A

5.16 NMOC Emission and Pipe Stress Calculations

In each of the above analysis the landfill is assumed to have 100 percent life remaining. If there is no MSW disposed in the landfill, the NMOC emission calculation will be zero because there is no source of emission. Once the landfill sequence begins

NMOC emission calculations can be made. To investigate NMOC emission and pipe stress limits, a landfill manager should consider the worst case scenario defined in Table 4 which involves a combination of all four of the alternatives evaluated. This is due to the maximum quantity of MSW that can be placed in the fill. If the alternative daily cover, shredder, compactor, and composting alternatives are selected and the landfill life is set to 100 percent filled the NMOC emission rate will be 14.1 tons per day. This is approximately one quarter of the action level of 55 tons per day. This indicates that with the selection of any combination of alternatives, the new source performance standard of 55 tons per year will not be exceeded. AAFB landfill will remain a Tier 1 facility and no additional equipment or studies will be required to control excess emissions. Additionally the equivalent pipe stress was calculated at 2.3 percent when all four of the alternatives were selected and analyzed. This was less than half of the 5.0 percent maximum deflection specified. The existing leachate collection pipe would theoretically support the additional MSW placed in the landfill.

6. CONCLUSION

Based on the difficulty, as well as the high cost, to site and construct municipal solid waste (MSW) landfills it is incumbent on landfill managers to evaluate all practical measures to extend the useful life of existing landfills. This study has investigated four alternative methods for optimizing landfill operations. These alternatives were evaluated and prioritized in terms of years gained in landfill life. In addition, a risk assessment of landfill operations was performed to provide environmental managers a method for prioritizing landfill compliance sites.

Landfills are not the final step in the cradle to grave concept. Production of leachate and landfill gases has a significant impact on the environment and directly impacts the health and safety of the workers and local community. The evaluated alternatives resulted in enhanced landfill performance as well as a decreasing the risks associated with disease vectors.

The main goal of this study was extending the existing landfill life at Andersen AFB, Guam. This goal was met through a comprehensive literature review and the construction of the Landfill Extension Modeling program written in Microsoft Excel. This program can be used at any point in the life of a landfill and has applicability to the wide range of landfill operations.

Using this program the analysis of four alternative methods for extending the life of landfill was made. A fifth, contracting, option was also made to investigate the possibility of outsourcing the management of solid waste disposal on Andersen AFB.

By implementing the four alternatives simultaneously the landfill may be extended to 48 years. This is nearly five times the life expectancy calculated at the initial site visit. A study should be conducted to determine the economic effectiveness of a composting program on AAFB. If there is no use or market for composted material the compost option could be excluded, but the landfill extension would still exceed 43 years.

In addition to extending the landfill life many other benefits to these alternatives were shown. Many of these alternatives had a direct positive impact on the occupational safety and health of the workers and surrounding community. Shredding specifically resulted in a reduction in the potential of spreading diseases by animal and insect vectors.

Alternative daily cover will meet EPA requirements as well as save valuable natural resources around the working face of the landfill site that would have been used as daily cover. Shredding combined with compaction will significantly increase the capacity of the landfill. Composting is not as critical of an option and would not significantly benefit AAFB operations.

The end results of placing more waste in the landfill and corresponding extending the life did not negatively impact the generation of Non-Methane Organic Compounds or significantly impact the existing leachate collection system.

Leachate recirculation decreases the time required for a landfill to reach stabilization. This is very significant to long range plans for the landfill. Due to the migration of toxic constituents in MSW it is beneficial for landfill managers to recirculate leachate in the MSW and treat the effluent leachate. This will minimize the risk associated with migration of these constituents through the subsurface limestone into the aquifer. Once the landfill has stabilized it can be mined. This would ensure the site is closed and would end the need for post-closure care.

Incinerating is not a cost-effective operation for AAFB. The government of Guam is currently investigating the implementation of a waste to energy facility to handle all of the waste generated on the island. Extending the life of the landfill is critical in insuring there is an alternative disposal option until this system is on line and has proven its operational effectiveness.

A risk assessment of the site concluded the biggest risk to the health and safety of the island community is the potential contamination of the aquifer. On an island, this is a very significant risk. In accordance with the guidelines on prioritizing compliance sites, the probability and severity categories were assigned values of occasional and critical based on the findings of this report.

7. RECOMMENDATIONS

7.1 Selection of Alternatives

Based on the preliminary findings of this study it would be prudent to implement the shredding, compacting and alternative daily cover alternatives in the landfill operations. Further, a current final cost analysis, using the program prior to the purchase of the corresponding support equipment, should be performed to insure there are no additional charges due to geographic location.

7.2 Landfill Mining

Currently AAFB is disposing MSW in a newly constructed double composite lined landfill. Once this new landfill has been closed and reaches stabilization a study should be conducted to determine the feasibility of landfill mining. The study should also include the potential to mine the "old" landfill, which forms the foundation of this "new" landfill. If Guam has the waste to energy facility operational at this point in time, dispose all of the non-reusable portions of the mined material. It is important to note that once stabilization is reached there will be less mass requiring disposal and the subsequent clean-up costs will be less. After the site is clean continue to sample the ground water monitoring wells to determine if the aquifer will require some form of remediation..

7.3 Recycling Efforts

The Landfill Extension Model program can also be used to evaluate the economics of any base's recycling program. This evaluation can assess the costs of the recycling effort against the time gained and landfill space saved or the cost effectiveness of the overall program.

7.4 Landfill Extension Modeling Program – Instruction Manual

An instruction manual has been included with this report to facilitate application of the model to virtually any landfill facility. Detail on all aspects, capabilities and limitations of the Landfill Extension Modeling Program are included in Appendix 2.

REFERENCES

1   ACGIH Booklet, "Threshold Limit Values (TLV's) for Chemical Substances and Physical Agents and Biological Exposure Indicies (BEI's)," American Conference of Governmental Industrial Hygienists, 1995-1996

2   Air Force Instruction 32-7080, "Draft, Compliance Assurance and Pollution Prevention," 1999

3   Bagchi, A., "Design, Construction, and Monitoring of Landfills,", NY, Wiley-Interscience, 1994

4   Bartone, C., "Economic and Policy Issues in Resource Recovery from Municipal Solid Wastes," Resources, Conservation and Recycling, 4, 1990, pp. 7-23

5   Boelens, J., De Wilde, B., De Baere, L., "Comparative Study on Biowaste Definition: Effects on Biowaste Collection, Composting Process and Compost Quality," Compost Science and Utilization, 1996, Vol 4, n1, pp. 60-72

6   Brunner, P., Stampfli, M., "Material Balance of a Construction Waste Sorting Plant." Resources, Conservation and Recycling, 11, 1993, 27-48

7   Cameron, R., "Mass Burning of MSW with Energy Recovery," J. of Env Eng, 114, n1, 1988, pp. 233-237

8   Chemical Engineering Plant Cost Index, Chemical Engineering, Vol 106, n 2, February 1999

9   Chilton, J., Chilton, K., "A Critique of Risk Modeling and Risk Assessment of Municipal Landfills Based on U.S. EPA techniques," Waste Management and Research, 1992, 10, pp. 505-516

10 Chugh, S., Clarke, W., "Effect of Recirculated Leachate Volume on MSW Degradation," Waste Manage Res., 1998, 16, n6, pp. 565-573

11 Duffy, D., "Alternative Daily Cover," MSW Management, May/June 1998, pp. 32-43

12 Dwyer, S., "Alternative Landfill Covers Pass the Test," Civil Engineering, Sep 98, pp. 50-52

13 Fedorak, P., Rogers, R., "Assessment of the Potential Health Risks Associated with the Dissemination of Micro-Organisms from a Landfill Site," Waste Management and Research, 1991, 9, pp. 537-563

14 Flynn, L., "Recycling: Will Roads Become 'Linear Landfills'?," Roads and Bridges, October 1992, pp. 65-70

15 Goddard, H., "The Benefits and Costs of Alternative Solid Waste Management Policies," Resources, Conservation and Recycling, 13, 1995, pp. 183-213

16 Ham, R., Reinhardt, J., Sevick, G., "Density of Milled and Unprocessed Refuse," ASCE, J. Env Eng Div, V104, n1, Feb 78, pp. 109-125

17 Hegberg, B., Hallenbeck, W., Brenniman, G., Wadden, R., "Report: Municipal Solid Waste Incineration with Energy Recovery in The USA," Waste Management and Research, 1991, n9, pp. 127-152

18 Hofmann Associates, "Evaluation of Small Modular Incinerators in Municipal Plants," U.S. EPA, Final Report SW-113c, 1976

19 Jones, D., "To Shred, or Not to Shred?," Waste Age, Vol 19, n6, 1988, pp. 114-118

20 Kashmanian, R., Spencer, R., "Cost Considerations of Municipal Solid Waste Compost: Production Versus Market Price," Compost Science and Utilization, 1993, Vol 1, n1, pp. 20-35

21 Keener, H., Dick, W., Marugg, C., Hansen, R., "Composting Spent Press-Molded, Wood Fiber Pallets Bonded with Urea-Formaldehyde: A Pilot Scate Evaluation," Compost Science and Utilization, 1994, Vol 2, n3, pp. 73-82

22 Kelley, M., "Equipment Selection for Landfills," Waste Age, Vol 17, n1, Jan 86, pp. 68-74

23 Lea. R., Tittlebaum, M., "Energy Cost Savings Associated with Municipal Solid Waste Recycling," J. of Env. Eng, 119, n6, 1993, pp. 1196-1217

24 Magnuson, A., "Leachate Recirculation," MSW Management, March/April, 1998, pp. 24-31

25 Maier, T., "Analysis Procedures for Design of Leachate Recirculation Systems," WQI, November/December, 1998, pp. 37-40

26 Millner, P., Olenchock, S., "Bioaerosols Associated with Composting Facilities," Compost Science and Utilization, 1994, Vol 2, n4, pp. 6-57

27 Reinhart, D., "Full-Scale Experiences with Leachate Recirculating Landfills: Case Studies," Waste Management and Research, 1996, 14, pp. 347-365

28 Reinhart, D., Al-Yousfi, A., "The Impact of Leachate Recirculation on Municipal Solid Waste Landfill Operating Characteristics," Waste Management and Research, 1998, 14, pp. 337-346

29 Reinhart, D., Townsend, T. "Landfill Bioreactor Design and Operation," FL, Lewis, 1998

30 Reinhart, D., Trainor, S., "Windrow Cocomposting of Municipal Biosolids and Yard Waste," Compost Science and Utilization, 1995, Vol 3, n2, pp. 38-46

31 Renkow, M., Safley, C., Chaffin, J., "A Cost Analysis of Municipal Yard Trimmings Composting," Compost Science and Utilization, 1994, Vol 2, n2, pp. 22-34

32 Rogers, H., Hitte, S., "Solid Waste Shredding and Shredder Selection," U.S. EPA, Report SW-140, 1972

33 Sibley, S., Butterman, W., "Metals Recycling in the United States," Resources, Conservation and Recycling, 15, 1995, pp. 259-267

34 Spencer, D., Temple, J., Forsythe, D., "Large Scale Rotary Shear Shredder Performance Testing,". J. of Energy Resources Technology, June 1985, Vol 107, pp. 289-296

35 Spencer, R., "Recycling Opportunities for Demolition Debris," BioCycle, November 1989, pp. 42-45

36 Stessel, R. "Recycling and Resource Recovery Engineering," Springer-Verlag Berlin Heidelberg NY, 1996

37 Steuteville, R., Goldstein, N., "The State of Garbage in America Part 1," Biocycle, May, 1993, pp. 42-50

38 Surprenant, G., Lemke, J., "Setting a Density Standard," Waste Age, Vol 25, n8, Aug 94, pp. 42-52

39 Tchobanoglous, G, Theisen, H, and Vigil, S. "Integrated Solid Waste Management: Engineering Principles and Management Issues," NY: McGraw-Hill., 1993

40 Tovanen, O., Veijanen, A., "Occupational Hygiene in Biowaste Composting," Waste Management and Research, 1998, 16, n6, pp. 525-540

41 USEPA (1995) – "Air Emissions From Municipal Solid Waste Landfills – Background Information for Final Standards and Guidelines," EPA-453/R-94-021, USEPA Research Triangle Park, NC

42 USEPA (1995a) – "Compilation of Air Pollutant Emission Factors – Volume I: Stationary Point and Area Sources Fifth Edition," AP-42, USEPA Research Triangle Park, NC

43 USEPA (1988) "Report to Congress – Solid Waste Disposal in the United States – Volume II," Washington, D.C., U.S.A.: U.S. Department of Commerce National Technical Information Service, USEPA

44 Waste Age Staff, "Guide to Landfill Equipment," Waste Age, Vol 14, n8, Aug 83, pp. 66-78

45 Wright, T., "To Cover or Not to Cover?," Waste Age, Vol 17, n3, Mar 86, pp. 41-44

APPENDICES

Title Page

Landfill Extension Model (LEM) Program

Captain Philip Preen and Dr. R. Jerry Murphy

Case Study: Andersen AFB, Guam

Pacific Air Force Command

June 1999
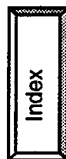
Index

Index Page

Title Page	....	Return to introduction
Initial Analysis Page	....	Input current specifications of landfill (landfill/lift dimensions, MSW input, % landfill consumed)
New Loading Page	....	Input planned specifications for landfill (lift dimensions, new MSW input, new option parameters)
Option Input Page	....	Input economic specifications for desired options (includes 4 pre-set and one expansion slot parameters)
Base Recycle Program Page	....	Input specifications for base recycle program (% of diverted waste stream, mass of diverted waste stream, analysis)
New Recycle Program Page	....	Input desired specifications for base recycle program (adjust % or mass diversion for analysis)
Community Recycle Page	....	Input specifications for community recycle program (specifications for adding community use to landfill)
Summary Page	....	The end result of all specification inputs and manipulations! (Verify regulatory compliance and integrity of leachate collection system)

Table 5.a Initial Analysis - Input Parameters

	Input Parameters			
A	Available Landfill Area	6	acres	
B	Length to Width Ratio	1	:	1
C	Average Depth of Area	4	ft	
D	Side Slope Ratio	3	:	1
E	Max. elev. Desired	45	ft	
F	Final Cover Depth	8	ft	
G	Intermediate cover	0.5	ft	
H	Base Population	8,950		
I	per capita	4.50	lb/day	
J	Terrace Width		ft	
K	daily cover loss	15%		
L	landfill compaction	1,000	lb/yd^3	
M	population growth	0%		
N	Tipping fee	90	$/ton	
O	shredding option	0%		
P	No. Lifts filled	0		
Q	% working lift filled	0.0%		
R	Landfill Input	0.0	ton/day	
S	NMOC concentration	0	ppm	
T	Methane Generation	0.00	liters/year	

All inputs required on this page pertain to current landfill operations
(All cells requiring input are white in the main program)

A　Footprint of usable landfill space, do not include liner anchor distance, AAFB value = 6 acres

B　Shape of foot print, (i.e., square = 1:1; 40' x 20' rectangle = 2:1), AAFB value 1:1

C　Average depth of usable landfill space footprint, AAFB value 4'

D　Construction specification for liner slope that outlines the disposal area, AAFB value = 3:1

E　Desired final height of completed landfill, value AAFB 45'

F　Cover depth of final cover (capping system), value 8'

G　Average depth of intermediate cover, value 0.5'

H　Base population currently living on base, utilizes base waste pickup system

I　MSW waste generation per capita for each resident described above, value = 4.50 lb/person-day

J　Working dimension for terrace if landfill ht. exceeds 50 feet (elevation), value 20'

K　Percentage of landfill lost due to use of soil as daily cover, value (10% - 20%)

L　Current level of landfill compaction; AAFB value using Cat D-5, 900 - 1,100 lb/yd^3

M　Anticipated annual population growth for base population, AAFB value 0%

N　Tipping fee derived from initial cost of landfill/MSW input; see Summary sheet

O　Shredding equipment in use? No = 0, Yes = addition space realized - AAFB value = 15 percent

P　Current number of lifts completed (i.e., lift number 1 is completely filled)

Q　Percentage of current lift filled (i.e., 45 percent of lift 2 is completely filled)

R　MSW input to landfill, AAFB value 13.1 tons/day

S　Subtitle D, NSPS, Tier 2 monitoring result input

T　Subtitle D, NSPS, Tier 3 monitoring result input

Table 5.b Initial Analysis - Input Parameters

		Lift (>gnd level) Design Inputs				
U	2	Height	9	ft		ok
		Slope Ratio	4	:	1	
V	3	Height	9	ft		ok
		Slope Ratio	4	:	1	
W	4	Height	9	ft		ok
		Slope Ratio	4	:	1	
X	5	Height	8	ft		ok
		Slope Ratio	4	:	1	
Y	6	Height		ft		n/a
		Slope Ratio		:		
Z	7	Height		ft		n/a
		Slope Ratio		:		
AA	8	Height		ft		n/a
		Slope Ratio		:		
AB	9	Height		ft		n/a
		Slope Ratio		:		
AC	10	Height		ft		n/a
		Slope Ratio		:		
AD	since closure		0	years		

All inputs required on this page pertain to current landfill operations

(All cells requiring input are white in the main program)

U-AC   Lift 1 volume calculations are made using the input parameter information (A - D)

See Table 7: Initial Calculation - Lift Analysis

The maximum number of lifts attainable are calculated on the initial calculation sheet

See Table 8: Initial Calculation - Fill and Cover Calculations – O

if the lift number is <= to the maximum number of lifts "ok" will be indicated

if the lift number is > the maximum number of lifts "n/a" will be indicated

Lift information is required for all lift blocks with an "ok".

Heights may vary between lifts depending on operator requirements.

AAFB value for slope ratio, Cat D-5 tractors, 4:1 slope

Slope heights were chosen arbitrarily for report calculations

Typical heights range from 8 to 12 feet

AD   Subtitle D, NSPS, NMOC emission estimate variable required for Scholl Canyon Model

If applicable, enter the number of years the landfill has been closed.

Table 6 Initial Analysis - Output Parameters

	Output Parameters		
A	Maximum # Lifts	5	
B	Ht Above gnd - no cap	36.5	
C	Ht Above gnd - w/cap	44.5	
D	Landfill input	13.1 ton/day	
		26,104 lb/day	
	Baseline Landfill Life		
E	Cumulative - MSW	4,776,275 ft³	
		176,899 yd³	
F	Cumulative - Intermediate Cover	364,890 ft³	
		13,514 yd³	
G	time to fill:	18 yrs	6 mo
	Remaining Life - based on amount filled		
H	Cumulative - MSW	4,776,275 ft³	
		176,899 yd³	
I	time to fill:	18 yrs	6 mo
J	Elapsed time:	0 yrs	0 mo
K	MSW Space Filled	0 yd³	
L	Overall Recycle Rate	35.2%	
M	% Landfill Filled	0.0%	

Output parameters are based on information provided in

Initial Analysis Table 5.a – 5.b; (no inputs are required in this Table)

A   Input from Table 8-O

B   Input from Table 8-P

C   * = (B)+(Initial Calculations-Table 6.a-F)

D   Input from Initial Analysis-Table 5.a-R if selected or Table 10-H

   * = D * 2,000 lb/ton

   Baseline status of landfill, derived from volumetric calculations

E   Input from Table 8-S

   * = E / 27 ft³/yd³

F   Input from Table 8-P

   * = F / 27 ft³/yd³

G   Input from Table 10-L&M; Initial landfill, derived from volumetric calculations

H   Input from Table 8-W

   * = H / 27 ft³/yd³

I   Input from Table 10-AL

J   Calculates difference between G and I

K   * = (E - H)

L   Input from Base Recycling Program page, see Table 23-J

M   * = 1 - (H / E)

   This space intentionally left blank

Table 7 Initial Calculations - Lift Analysis

A	average depth	4 ft	
B	brim slope	3 : 1	
C	slope width	12 ft	
D	slope height	4 ft	
E	Terrace	20 ft	
F	inner cell (a)	949,587 ft³	Base
G	outer cells (b)	24,539 ft³	
H	outer cells (c)	23,387 ft³	
I	total 1st lift volume	997,513 ft³	36,945 yd³
J	Interm. Cover Depth	0.5 ft	
K	Intermediate Cover	130,680 ft³	4,840 yd³

C1

	Lift Height	9 ft	
	Lift Slope	4 : 1	
	slope width	36 ft	Second
	slope height	9 ft	Lift
	inner cell (a)	1,736,337 ft³	
	outer cell (b)	82,820 ft³	
	outer cell (c)	71,156 ft³	
	Total 2nd lift volume	1,890,313 ft³	70,012 yd³
	Interm. Cover Depth	0.5 ft	
	Intermediate Cover	96,463 ft³	3,573 yd³

(A)	Lift Height	9 ft			
(B)	Lift Slope	4 : 1			
(C)	slope width	36 ft	Third Lift		C2
(D)	slope height	9 ft			D1
(F)	inner cell (a)	1,213,746 ft²		963,539 ft³	L
(G)	outer cell (b)	71,156 ft³		64,670 ft³	M
(H)	outer cell (c)	59,492 ft³		53,006 ft³	N
(I)	Total 3rd lift volume	1,344,394 ft³		1,081,425 ft³	O
(I)	Total 3rd lift volume	1,344,394 ft³		49,792 yd³	P
(J)	Interm. Cover Depth	0.5 ft			
(K)	Intermediate Cover	67,430 ft²		53,541 ft³	Q
(K)	Intermediate Cover	67,430 ft³		2,497 yd³	R

(This process continues to the 10th lift)

Table 7 – Footnotes
(No inputs are required on this page)

A   Input from Table 5.a-C

B   Input from Table 5.a-D

C   * = (slope run / slope rise) * slope height

D   Input from Table 5.a-C

E   Input from Table 5.a-J

F   Volume Calculation for inner cell

    * = [(footprint length) - 2 * C] *
    [(footprint width) - 2 * C]

G   Volume Calculation for outer cells (width)

    * = [(C * D) / 2] * footprint width * 2

H   Volume Calculation for inner cells (length)

    * = [(C * D) / 2] * (footprint Length - 2 * C) * 2

I   Total volume calculation for lift

    * = F + H + I

    * also in yd^3 = # ft^3 / (27 ft^3/yd^3)

J   Input from Table 5.a-G

K   Volume of intermediate cover required

    * = area of footprint * J

    D - K is repeated for lifts 2 through 10
    Using the corresponding lift inputs
    From the Initial Analysis page
    In addition to the adjustment for the individual
    Slope width, all previous slope widths are
    Subtracted in F and H correspondingly

L   Volume calculation for inner cell

    * = [footprint length - 2*E - 2*C1 - 2*C2] *
    [footprint width - 2*E - 2*C1 - 2*C2] * C2

M   Volume Calculation for outer cell (width)

    * = (C2 * D1)/2 * (footprint width - 2*C1 - 2*E)

N   Volume Calculation for outer cell (Length)

    * = (C2 * D1)/2 *
    (footprint length - 2*C1 - 2*C2 - 2*E)

O   Total volume for lift

    * = L + M + N

P   If lift height > 50 feet O is used, if not (I)

Q   * = inner cell volume/slope height*cover depth

    * = (L / D1) * (J)

R   if lift height > 50 feet Q is used, if not (K)
    Calculations L through R are repeated for
    lifts 4 through 10. In addition to the
    adjustment for the individual slope width
    all previous slope widths are subtracted in
    L and N respectively.

    Starting with the third lift an assumption is
    Made that the landfill height may exceed
    50 feet. An additional calculation is made
    To account for the terrace width.
    An assumption is also made the landfill will
    Not require more than one terrace.

Table 8 Initial Calculations - Fill and Cover Calculations

A	Intermediate cover		0.5 ft		
B	inner - footprint	6 acres	or	261,360 ft²	
C	length to width ratio		1	:	1
D	dimensions-length x width	511.2 ft		x	511.2 ft
E					

	MSW ft³ (F)	MSW yd³ (G)	Cover ft³ (H)	Cover yd³ (I)	Cumulative MSW ft³ (J)	Cumulative MSW yd³ (K)	Cumulative Cover ft³ (L)	Cumulative Cover yd³ (M)	Cumulative Height ft (N)
1	997,513	36,945	130,680	4,840	997,513	36,945	130,680	4,840	0
2	1,890,313	70,012	96,463	3,573	2,887,826	106,957	227,143	8,413	9
3	1,344,394	49,792	67,430	2,497	4,232,220	156,749	294,573	10,910	18.5
4	891,787	33,029	43,582	1,614	5,124,007	189,778	338,155	12,425	28.0
5	495,140	18,339	26,735	990	5,619,417	208,117	364,890	13,514	36.5
6	0	0	0	0	0	0	0	0	0.0
7	0	0	0	0	0	0	0	0	0.0
8	0	0	0	0	0	0	0	0	0.0
9	0	0	0	0	0	0	0	0	0.0
10	0	0	n/a	n/a	0	0	0	0	0.0

O				lifts maximum					
P				5	5,619,417	208,117	364,890	13,514	36.5
Q	cover loss	15%			4,776,275	176,899			
R	shredder	0%			5,619,417	208,117			
S					4,776,275	176,899			

			Cum. MSW ft³ (V)	yd³	Cum. MSW to be filled ft³ (W)	yd³
No. lifts filled	0		0	0	4,776,275	176,899
% working lift filled	0%	0%				
(T)		(U)				

Table 8 - Footnotes

Calculation to determine the available MSW volume and intermediate cover

(No inputs are required on this page)

A   Input from Table 5.a-C

B   Acres input from Table 5.a-A and converted to ft^2 - # acres * 43560 ft^2/acre

C   Length to width ratios input from Table 5.a-B

D   length calculation = [# ft^2 (B) / (width ratio/length ratio (C))]$^{.5}$ and width calculation = [(width ratio/length ratio) * length calculation]

E   Lift identifier number

F-I Automatically fills the calculated value of associated lifts, once the maximum number of lifts is exceeded a zero will register

J-M Calculates a running cumulative total of all lifts using the associated values

N   Calculates a running cumulative total of all associated lift heights

O   Based on the maximum desired height from Table 5.a-E, the maximum number of lifts was calculated using the cumulative height information (N)

P   The maximum values of J - N are shown here

Q   The percent cover loss is input from Table 5.a-K. This percentage is subtracted from the cumulative MSW figures = P – (P * percent cover loss)

R   The percentage gained from the shredder option is input from Table 5.a-O

This percentage is added to the cumulative MSW figures = P + (P * percent shredder gain)

S   The total of cumulative effect of the cover loss and shredder are shown here.

* = P - (P * percent cover loss) + (P * percent shredder gain)

T   Values for the percentage of landfill used were input from Table 5.a-P&Q

U   Finds the corresponding cumulative MSW from W based on the number of lifts filled. Also finds the corresponding (lift +1) information and

multiplies it by the percentage cumulative MSW filled (T)

V   * = U - (U * percent cover loss) + (U * percent shredder gain)

U = total of two values calculated in U based on percentage of landfill filled

W   The remaining landfill available = S – V

Table 9 Initial Calculations - Leachate Pipe Stress Calculations

	Assumptions:			
A	6" HDPE pipe, embedded in gravel or sand	B =	0.09	
B	stiffness equivalent to Schedule 80 pipe	(F/ΔY) =	700	
C	0.432" wall thickness	D =	2	
D	rounded gravel encases pipe	E' =	200	
	(not compacted)			
E	waste to cover ratio	4	1	
F	Thickness of daily cover + final cover	SC =	14.5	ft
G	Unit weight of fill 1,000 lb/yd³		37.0	lb/ft³
H	Unit weight of soil 1,000 lb/yd³		37.0	lb/ft³
I	Leachate head on liner		3	ft
J	water density		62.4	lb/ft³
K	Pressure on pipe	P =	11.7	psi
L	% (ΔDp)		1.8	%

(No inputs are required on this page)
Calculations to determine the stress placed on the leachate collection pipes
Assumptions: 6 inch HDPE pipe, not compacted, embedded in rounded gravel
  0.432 inch wall thickness
  Compaction density of soil = 1,000 lb/yd³, used in H
  worst case, head on liner = 3 feet, used in I

A-D Values shown in Section 2.10 of report

E If soil is used for a daily cover, waste:cover = 4:1,
   (4 / percentage typically lost due to daily cover (15%)) * Q

F * = (landfill depth-final cover depth)*(1/(waste:cover))+final cover depth

G * = compaction density from Table 5.a-L / 27 ft3/yd3

H * = Assumed value for compaction density of soil / 27 ft³/yd³

I Assumed worst case value

J Density of water

K * = (waste depth-final cover depth * unit wt of waste)+(SC * unit wt of soil)+
   (Leachate head * water density)

L Modified Iowa formula
   * = (Z * X * AH * 100) / ((0.149 * (Y)) + (0.061 * AA))

Table 10 Initial Calculations -- Time To Fill Calculations

	Baseline Time to Fill			Life Remaining Based on Amount Filled >1 year			Life Remaining Based on Amount Filled <1 year	
A	176,899	yd³	R	176,899	yd³	AE	176,899	yd³
B	1		S	1				
C	2015	2016	T	2012	2013			
D	18	yrs	U	18	yrs			
E	171,504.9	yd³	V	171,504.9	yd³			
F	5394.2	yd³	W	5394.2	yd³			
G	4,764.0	9,463.0	X	4,764.0	9,463.0			
H	13.1	ton/day	Y	13.1	ton/day	AF	13.1	ton/day
I	6	months	Z	6	months	AG	226	months
J	18	yrs	AA	18	yrs	AH	0	months
K	6	months	AB	7	months	AI	18	year
L	18	yrs	AC	18	yrs	AJ	18	year
M	6	months	AD	6	months	AK	0	months
			AL	New Time To Fill 18	years	New Time To Fill 6		months

	projected growth	
N	0%	per capita
O	4.00	compaction
P	1,000	Max
Q	20.0	

Table 10 – Footnotes

(No inputs are required on this page)

A — Input from cumulative MSW volume, Table 8-S

B — Code to find the value A represented in Table 11-H

C — Using B returns the corresponding year value from Table 11-A

D — Counts the number of years to reach the value of A

E — Returns the value of cumulative MSW found in Table 11-H

F — * = A - E

G — Returns the adjusted ton/year value based on B

H — Returns adjusted ton/day value based on B, converts # * 2,000 lb/ton / initial compaction density

I — * = F / G * 12

J — * = trunc(I / 12) + D

K — * =((I / 12) - [TRUNC(I / 12)) * 12]

L — Returns the calculated baseline year

M — Returns the calculated baseline month

N-P — Input from Table 5.a-M, I, & L, used in Table 11

Q — Returns the maximum value found in table 11-C

R — Input from cumulative MSW, Table 8-W

S-AD — Same calculations as A - M above

AE — Input from cumulative MSW, Table 8-W

AF — Returns the adjusted ton/day value based on S, Table 11-E

AG — * = AE * initial compaction density / 2,000 lb/ton / AF / 30 days/month

AH — Checks to see if AG exceeds 12 months, returns appropriate value if it does

AI — If AH exceeds 12, returns appropriate number of years

AJ — * = AI

AK — * = AH

AL — Returns the number of years and months calculated in AC - AD or AJ - AK respectively

Table 11 Initial Calculations - MSW Generation Calculations

A Calendar Year	B Population	C Generated MSW ton/day	D total Diverted ton/day	E adjusted MSW ton/day	F adjusted MSW ton/year	G adjusted cumulative weight	H adjusted cumulative volume
1998	8,950	20.1	7.1	13.1	4,764.0	4,764.0	9,490.0
1999	8,950	20.1	7.1	13.1	4,764.0	9,528.0	19,056.0
2000	8,950	20.1	7.1	13.1	4,764.0	14,292.0	28,584.0
2001	8,950	20.1	7.1	13.1	4,764.0	19,056.0	38,112.0
2002	8,950	20.1	7.1	13.1	4,764.0	23,820.0	47,640.0
2003	8,950	20.1	7.1	13.1	4,764.0	28,584.0	57,168.0
2004	8,950	20.1	7.1	13.1	4,764.0	33,348.0	66,696.0
2005	8,950	20.1	7.1	13.1	4,764.0	38,112.0	76,224.0
2006	8,950	20.1	7.1	13.1	4,764.0	42,876.0	85,752.0
2007	8,950	20.1	7.1	13.1	4,764.0	47,640.0	95,280.0
2008	8,950	20.1	7.1	13.1	4,764.0	52,404.0	104,808.0
2009	8,950	20.1	7.1	13.1	4,764.0	57,168.0	114,336.0
2010	8,950	20.1	7.1	13.1	4,764.0	61,932.0	123,864.0
2011	8,950	20.1	7.1	13.1	4,764.0	66,696.0	133,392.0
2012	8,950	20.1	7.1	13.1	4,764.0	71,460.0	142,920.0
2013	8,950	20.1	7.1	13.1	4,764.0	76,224.0	152,448.0
2014	8,950	20.1	7.1	13.1	4,764.0	80,988.0	161,976.0
2015	8,950	20.1	7.1	13.1	4,764.0	85,752.0	171,504.0
2016	8,950	20.1	7.1	13.1	4,764.0	90,516.0	181,032.0
2017	8,950	20.1	7.1	13.1	4,764.0	95,280.0	190,560.0
2018	8,950	20.1	7.1	13.1	4,764.0	100,044.0	200,088.0
2019	8,950	20.1	7.1	13.1	4,764.0	104,808.0	209,616.0
2020	8,950	20.1	7.1	13.1	4,764.0	109,572.0	219,144.0

(This process continues through year 2097)

A (No inputs are required on this page)
The year in this program is arbitrary, this time frame was chosen for ease of programming
B First cell information is input from Table 5.a-H, Other values are automatically filled down.
C * = B * Table 9-O
D * = C - E
E * = C * (1 ~ (Base Recycling Efficiency # [Table 6-AP])
F * = E * 365 day/year
G * = a cumulative running total of (F)
H * = G * 2,000 lb/ton / initial compaction density

Table 12.a New Loading - New Input Parameters

New Input Parameters	new	initial
A	Base Pop.	8,950	8,950
B	Community Pop.	0	n/a
C	Base Growth	0.0%	0%
D	Community Growth	0.0%	n/a
E	Per Capita Base	4.50	4.50
F	Per Capita Community	0.00	n/a
G	Landfill Comp (lb/yd^3)	1,000	1,000
H	Intermediate Cover (ft)	0.5	0.5
I	New MSW Input	13.1	ton/day
J	Daily Cover Loss	15%	15%
K	Shredding Option	15%	0%
L	Status	Feasible	
M	No. Lifts filled	0	
	% Working Lift Filled	0.0%	
	% Landfill Filled	0.0%	
N	Tipping Fee $/ton	90	90
O	Base Landfill Input	0.0	13.1
P	Comm. Landfill Input	0.0	n/a

All inputs required on this page pertain to the desired "New" landfill operations
(All cells requiring input are white in the main program)

A   All data in the initial column is input from the Initial Analysis page

A   Base population, (i.e., mission change, increase in permanent party assigned)

B   Input from Table 21-C

C   Base population annual growth estimate

D   Input from Table 21-E

E   Base waste generation per capita, lbs/person-day

F   Input from Table 21-D

G   Input from Table 19-G "Compactor Alternative"

H   Intermediate cover, (i.e., changes to cover material/thickness)

I   Input from Table 17-Q

J   Input from Table 19-G "ADC"

K   Input from Table 19-G "Shredder"

L   * = if Elapsed Time < 0 then "Not Feasible", if > 0 then "Feasible"

M   Input from Table 5.a-P

N   Input from Table 5.a-Q

O   Input from Table 6-AQ

P   Tipping fee derived from initial cost of landfill/MSW input; see Summary sheet

Q   MSW input to landfill,
(i.e., previous MSW waste stream diversion now requires landfill disposal)

R   When using the contract option and including the community waste stream
enter the community MSW waste stream in (ton/day)

Table 12.b New Loading - Input Parameters

Lift (>gnd level) Design Inputs						
Q	2	Height	9	ft		ok
		Slope Ratio	4	:	1	
R	3	Height	9	ft		ok
		Slope Ratio	4	:	1	
S	4	Height	9	ft		ok
		Slope Ratio	4	:	1	
T	5	Height	8	ft		ok
		Slope Ratio	4	:	1	
U	6	Height	0	ft		n/a
		Slope Ratio	0	:	1	
V	7	Height	0	ft		n/a
		Slope Ratio	0	:	1	
W	8	Height	0	ft		n/a
		Slope Ratio	0	:	1	
X	9	Height	0	ft		n/a
		Slope Ratio	0	:	1	
Y	10	Height	0	ft		n/a
		Slope Ratio	0	:	1	
Z	Initial Base Recycle Rate					35.2%

All inputs required on this page pertain to the desired "New" landfill operations (All cells requiring input are white in the main program)

Lift 1 volume calculations are made using Table 5.a-A-D; see Table 12: New Calculations - Lift Analysis

Q-Y   the maximum number of lifts attainable are calculated on the New Calculation sheet see Table 16: New Calculations - Fill and Cover Calculations - O

If the lift number is <= to the maximum number of lifts "ok" will be indicated

If the lift number is > the maximum number of lifts "n/a" will be indicated

Lift information is required for all lift blocks with an "ok".

Heights may vary between lifts depending on operator requirements.

Enter the new slope information relevant to the new operations/equipment

Typical heights range from 8 to 12 feet

Z   Input from Base Recycle Program, see Table 23-J

Table 13　New Loading - New Output Parameters

New Output Parameters	5	Lifts
A　Maximum # Lifts	5	Lifts
B　Ht Above gnd - no cap	36.5	ft
C　Ht Above gnd - w/cap	44.5	ft
D　Original Landfill Input	13.1	ton/day
Landfill Life		
E　Cumulative - MSW	4,776,275 ft³	176,899 yd³
F　Cumulative - Intermediate Cover	364,890 ft³	13,514 yd³
G　time to fill:	18 yrs	6 mo
Remaining Life - based on New Loading		
H　Cumulative - MSW	5,619,147 ft³	208,117 yd³
I　Original time to fill:	18 yrs	6 mo
J　Elapsed time:	0 yrs	0 mo
K　New time to fill:	21 yrs	10 mo
L　Gain	3 yrs	4 mo
M　Loss	0 yrs	0 mo
N　Recycle Rate - base	35.2%	
O　Rec. Rate - community	0.0%	

Output parameters are based on information provided in Tables 12.a-12.b

(no inputs are required in this Table)

A　Input from Table 15-O

B　Input from Table 15-P

C　* = (B)+(Table 5.a - F)

D　Input from Table 12.a-N If selected or Table 17-Q

Baseline status of landfill, derived from volumetric calculations

E　Input from Table 6-H

* = I / 27 ft³/yd³

F　Input from Table 6-J

* = J / 27 ft³/yd³

G　Input from Table 6-K

Initial status of landfill, derived from volumetric calculations adjusted for % filled

H　Input from Table 15-U

* = H / 27 ft³/yd³

I　Input from Table 6-I; Calculates the difference between G and I

New status of landfill, derived from volumetric calcs, adjusted for new specifications

J　* = G - I

K　Input from Table 17-AD

If J = I then, "No Change"; "New Time To Fill"

L　* = if J > I, then "Gain" and J - I; otherwise blank

M　* = if J < I, then "Loss" and I - J; otherwise blank

N　New recycle effort, Input from New Base Recycling Program page, see Table 23-J

O　Input from Community Recycling Program page, see Table 23-J

Table 14 New Calculations - Lift Analysis

A	average depth	4 ft		
B	brim slope	3 : 1		
C	slope width	12 ft		
D	slope height	4 ft		
E	Terrace	20 ft		
F	inner cell (a)	949,587 ft³	Base	
G	outer cells (b)	24,539 ft³		
H	outer cells (c)	23,387 ft³		
I	total 1st lift volume	997,513 ft³		36,945 yd³
J	Interm. Cover Depth	0.5 ft		
K	Intermediate Cover	130,680 ft³		4,840 yd³
	Lift Height	9 ft		
	Lift Slope	4 : 1	Second Lift	
	slope width	36 ft		
	slope height	9 ft		
	inner cell (a)	1,736,337 ft³		
	outer cell (b)	82,820 ft³		
	outer cell (c)	71,156 ft³		
	Total 2nd lift volume	1,890,313 ft³		70,012 yd³
	Interm. Cover Depth	0.5 ft		
	Intermediate Cover	96,463 ft³		3,573 yd³ C1

(A)	Lift Height	9 ft			
(B)	Lift Slope	4 : 1			
(C)	slope width	36 ft	Third Lift		C2
(D)	slope height	9 ft			D1
(F)	inner cell (a)	1,213,746 ft³	963,539 ft³		L
(G)	outer cell (b)	71,156 ft³	64,670 ft³		M
(H)	outer cell (c)	59,492 ft³	53,006 ft³		N
(I)	Total 3rd lift volume	1,344,394 ft³	1,081,425 ft³		O
	Total 3rd lift volume	1,344,394 ft³	49,792 yd³		P
(J)	Interm. Cover Depth	0.5 ft			
(K)	Intermediate Cover	67,430 ft³	53,541 ft³		Q
	Intermediate Cover	67,430 ft³	2,497 yd³		R

(This process continues to the 10th lift)

Table 14 - Footnotes
(No inputs are required on this page)

A Input from Table 5.a-C

B Input from Table 5.a-D

C * = (slope run / slope rise) * slope height

D Input from Table 5.a-C

E Input from Table 5.a-J

F Volume Calculation for inner cell
   * = [(footprint length) - 2 * C] *
   [(footprint width) - 2 * C]

G Volume Calculation for outer cells (width)
   * = [(C * D) / 2] * footprint width * 2

H Volume Calculation for inner cells (length)
   * = [(C * D) / 2] * (footprint Length - 2 * C) * 2

I Total volume calculation for lift
   * = F + H + I
   * also in yd³ = # ft³ / (27 ft³/yd³)

J Input from Table 12.a-H

K Volume of intermediate cover required
   * = area of footprint * J

D - K is repeated for lifts 2 through 10
using the corresponding lift inputs
from the New Loading page
In addition to the adjustment for the individual
slope width, all previous slope widths are
subtracted in F and H correspondingly

L Volume calculation for inner cell
   * = [footprint length - 2*E -2*C1 - 2*C2] *
   [footprint width - 2*E - 2*C1 - 2*C2] * C2

M Volume Calculation for outer cell (width)
   * = (C2 * D1)/2 * (footprint width - 2*C1 - 2*E)

N Volume Calculation for outer cell (Length)
   * = (C2 * D1)/2 *
   (footprint length - 2*C1 - 2*C2 - 2*E)

O Total volume for lift
   * = L + M + N

P * If lift height > 50 feet O is used, if not (I)

Q * = inner cell volume/slope height*cover depth
   * = (L / D1) * (J)

R * if lift height > 50 feet Q is used, if not (K)
   Calculations L through R are repeated for
   lifts 4 through 10. In addition to the
   adjustment for the individual slope width
   all previous slope widths are subtracted in
   L and N respectively.

Starting with the third lift an assumption is
made that the landfill height may exceed
50 feet. An additional calculation is made
to account for the terrace width.
An assumption is also made the landfill will
not require more than one terrace.

Table 15 New Calculations - Fill and Cover Calculations

A	Intermediate cover	0.5		
B	inner - footprint	6 acres	or	261,360 ft²
C	length to width ratio	1	:	1
D	dimensions-length x width	511.2 ft	x	511.2 ft
E				

	F	G	H	I	J	K	L	M	N
	MSW ft³	MSW yd³	Cover ft³	Cover yd³	Cumulative MSW ft³	Cumulative MSW yd³	Cumulative Cover ft³	Cumulative Cover yd³	Cumulative Height ft
1	997,513	36,945	130,680	4,840	997,514	36,945	130,680	4,840	0
2	1,890,313	70,012	96,463	3,573	2,887,826	106,957	227,143	8,413	9
3	1,344,394	49,792	67,430	2,497	4,232,220	156,749	294,573	10,910	18.5
4	891,787	33,029	43,582	1,614	5,124,007	189,778	338,155	12,524	28.0
5	495,132	18,338	26,735	990	5,619,147	208,117	364,890	13,514	36.5
6	0	0	0	0	0	0	0	0	0.0
7	0	0	0	0	0	0	0	0	0.0
8	0	0	0	0	0	0	0	0	0.0
9	0	0	0	0	0	0	0	0	0.0
10	0	0	n/a	n/a	0	0	0	0	0.0

O				lifts maximum					
P				5	5,619,147	208,117	364,890	13,514	36.5
Q	cover loss	15%		-	842,872	176,899			
R	shredder	15%		+	842,872	239,334			
S	Compost	0.0%		n/a	0	0			
T					5,619,147	208,117			
U	Cum. MSW to be filled			5,619,147 ft³					
				208,117 yd³					
V	No. Lifts filled	0	0						
W	% working lift filled	0%	0%						

Table 15 – Footnotes

Calculation to determine the available MSW volume and intermediate cover
(No inputs are required on this page)

A　Input from Table 12.a-H

B　Acres input from Table 5.a-A and converted to ft² - # acres * 43560 ft²/acre

C　Length to width ratios input from Table 5.a-B

D　Length calculation = [# ft² (B) / (width ratio/length ratio (C))]$^{.5}$ and Width calculation = [(width ratio/length ratio) * length calculation]

E　Lift identifier number

F-I　Automatically fills the calculated value of the associated lifts, once the maximum number of lifts is exceeded a zero will register

J-M　Calculates a running cumulative total of all lifts using the associated values

　　Based on V input, reports zero in each filled lift

　　Based on W input, report a value = J - (J * W)

N　Calculates a running cumulative total of all associated lift heights

O　Based on the maximum desired height from Table 5.a-E, the maximum number of lifts was calculated using the cumulative height information (N)

P　The maximum values of J - N are shown here

Q　The percent cover loss is input from the Table 19-G. This percentage is subtracted from the cumulative MSW figures = P * percent cover loss

R　The percentage gained from the shredder option is input from the Table 19-G; this percentage is added to the cumulative MSW figures = P * percent shredder gain

S　The percentage is added to the cumulative MSW figures = P * percent compost

T　The total of cumulative effect of the cover loss and shredder are shown here.

　　* = P - (Q) + (R) + (S)

U　* = values obtained in T

V　* value input from Table 5.a-P

W　* value input from Table 5.a-Q

Table 16 New Calculations - Leachate Pipe Stress Calculations

	Assumptions:				
A	6" HDPE pipe, embedded in gravel or sand	B =	0.09		
B	Stiffness equivalent to Schedule 80 pipe	(F/ΔY) =	700		
C	0.432" wall thickness	D =	2		
D	Rounded gravel encases pipe	E' =	200		
	(not compacted)				
E	Waste to cover ratio	4.0	1		
F	Thickness of daily cover + final cover	SC =	14.5		ft
G	Unit weight of fill	1,000 lb/yd³	37.0		lb/ft³
H	Unit weight of soil	1,000 lb/yd³	37.0		lb/ft³
I	Leachate head on liner		3		ft
J	Water density		62.4		lb/ft³
K	Pressure on pipe	P =	11.7		psi
L	%(ΔY/D_p)		1.8		%

(No inputs are required on this page)

Calculations to determine the stress placed on the leachate collection pipes

Assumptions: 6 inch HDPE pipe, not compacted - embedded in rounded gravel and a 0.432 inch wall thickness

A-D Values shown in section 2.10 of report

E if soil is used for a daily cover, waste:cover = 4:1, (not compacted)

(4 / percentage typically lost due to daily cover (15%)) * Q

F * = (landfill depth-final cover depth)*(1/(waste:cover))+final cover depth

G * = compaction density from Table 19-G / 27 ft3/yd3

H * = Assumed value for compaction density of soil / 27 ft³/yd³

I Assumed worst case value

J Density of water

K * = (waste depth-final cover depth * unit wt of waste)+(SC * unit wt of soil)+

(leachate head * water density)

L Modified Iowa formula

* = (Z * X * AH * 100) / ((0.149 * (Y)) + (0.061 * AA))

Table 17 New Calculations - Time To Fill Calculations

		Base		max		Community		
A	Elapsed time:	0.0	years	0.000		0.00	months	
B		0.0		0.0		1.00		
C	Per capita 1	4.5		20.1		per capita 2	0.00	G
D	Population	8,950		F		Population	0	H
E	Pop. Growth	0.0%				Pop. Growth	0.0%	I

Time to fill remaining landfill space

	>1 year		<1 year		
J	208,116	yd³	208,116	yd³	W
K	1		0		X
L	2018		0		Y
			2019		
M	21	yrs			
N	200,089.0	yd³	0.0	yd³	Z
O	8027.0	yd³			
P	4,764.0	yd³	9,528.0		
Q	13.1	ton/day	0.0	ton/day	AA
R	10	months	0	months	AB
S	21	yrs			
T	10	months			
U	21	yrs			
V	10	months	0	months	AC

	New Time To Fill			
	21	years	10 months	AD

Table 17 - Footnotes
(No inputs are required on this page)

A   Input from Table 13-AJ

B   Code used by Table 18, all information between day 1 of landfill and this data will register as zero

C   Input from Table 12.a-E

D   Input from Table 12.a-A

E   Input from Table 12.a-C

F   Returns maximum value of Table 18-D

G   Input from Table 21-D

H   Input from Table 21-C

I   Input from Table 21-E

J   Based on information from New Loading page, Table 15-U

K   Code to find the value (J) represented in Table 18

L   Using K returns the corresponding year value from Table 18-A

M   Counts the number of years to reach the value of (J)

N   Returns the value of cumulative MSW found in Table 18-N

O   * = J – N

P   Returns the adjusted ton/year value based on B

Q   Returns the adjusted ton/day value based on B, converts # * 2,000 lb/ton / initial compaction density

R   * = O / P * 12

S   * = trunc(R / 12) + M

T   * =((R / 12) - [TRUNC(R / 12)) * 12]

U   Returns the calculated new year

V   Returns the calculated new month

W   Based on information from New Loading page, Table 15 - U

X   Code to find the value (W) represented in Table 18

Y   Returns the year value found in table 18-A

Z   Returns the adjusted cumulative volume, Table 18-N

AA Returns the adjusted ton/day value based on X, Table 18-K

AB * = AA * initial compaction density / 2,000 lb/ton / AF / 30 days/month

AC Checks to see if AB exceeds 12 months, returns zero value if it does

AD Returns the number of years and months calculated in U - V or AC respectively

Table 18 New Calculation – MSW Generation Calculations

| Calendar Year | Base Population (1) | Community Population (2) | generated MSW (1) ton/day | generated MSW (2) ton/day | Total generated ton/day | Diverted MSW (1) ton/day | Diverted MSW (2) ton/day | adjusted MSW (1) ton/day | adjusted MSW (2) ton/day | total adjusted ton/day | total adjusted ton/year | adjusted cumulative weight | adjusted cumulative volume |
A	B	C	D	E	F	G	H	I	J	K	L	M	N
1998	8,950	0	20.1	0.0	7.1	0.0	0.0	13.1	0.0	13.1	4,764.0	4,764.0	9,528.0
1999	8,950	0	20.1	0.0	7.1	0.0	0.0	13.1	0.0	13.1	4,764.0	9,528.0	19,056.0
2000	8,950	0	20.1	0.0	7.1	0.0	0.0	13.1	0.0	13.1	4,764.0	14,292.0	28,584.0
2001	8,950	0	20.1	0.0	7.1	0.0	0.0	13.1	0.0	13.1	4,764.0	19,056.0	38,112.0
2002	8,950	0	20.1	0.0	7.1	0.0	0.0	13.1	0.0	13.1	4,764.0	23,820.0	47,640.0
2003	8,950	0	20.1	0.0	7.1	0.0	0.0	13.1	0.0	13.1	4,764.0	28,584.0	57,168.0
2004	8,950	0	20.1	0.0	7.1	0.0	0.0	13.1	0.0	13.1	4,764.0	33,348.0	66,696.0
2005	8,950	0	20.1	0.0	7.1	0.0	0.0	13.1	0.0	13.1	4,764.0	38,112.0	76,224.0
2006	8,950	0	20.1	0.0	7.1	0.0	0.0	13.1	0.0	13.1	4,764.0	42,876.0	85,752.0
2007	8,950	0	20.1	0.0	7.1	0.0	0.0	13.1	0.0	13.1	4,764.0	47,640.0	95,280.0
2008	8,950	0	20.1	0.0	7.1	0.0	0.0	13.1	0.0	13.1	4,764.0	52,404.0	104,808.0
2009	8,950	0	20.1	0.0	7.1	0.0	0.0	13.1	0.0	13.1	4,764.0	57,168.0	114,336.0
2010	8,950	0	20.1	0.0	7.1	0.0	0.0	13.1	0.0	13.1	4,764.0	61,932.0	123,864.0
2011	8,950	0	20.1	0.0	7.1	0.0	0.0	13.1	0.0	13.1	4,764.0	66,696.0	133,392.0
2012	8,950	0	20.1	0.0	7.1	0.0	0.0	13.1	0.0	13.1	4,764.0	71,460.0	142,920.0
2013	8,950	0	20.1	0.0	7.1	0.0	0.0	13.1	0.0	13.1	4,764.0	76,224.0	152,448.0
2014	8,950	0	20.1	0.0	7.1	0.0	0.0	13.1	0.0	13.1	4,764.0	80,988.0	161,976.0
2015	8,950	0	20.1	0.0	7.1	0.0	0.0	13.1	0.0	13.1	4,764.0	85,752.0	171,504.0
2016	8,950	0	20.1	0.0	7.1	0.0	0.0	13.1	0.0	13.1	4,764.0	90,516.0	181,032.0
2017	8,950	0	20.1	0.0	7.1	0.0	0.0	13.1	0.0	13.1	4,764.0	95,280.0	190,560.0
2018	8,950	0	20.1	0.0	7.1	0.0	0.0	13.1	0.0	13.1	4,764.0	100,044.0	200,088.0
2019	8,950	0	20.1	0.0	7.1	0.0	0.0	13.1	0.0	13.1	4,764.0	104,808.0	209,616.0
2020	8,950	0	20.1	0.0	7.1	0.0	0.0	13.1	0.0	13.1	4,764.0	109,572.0	219,144.0

(This process continues through year 2097)

Table 18 – Footnotes

(No inputs are required on this page)

A The year in this program is arbitrary, this time frame was chosen for ease of programming

B First cell information is input from Table 17-D

    Population growth for remaining cells = first cell + (first cell * (Table 17-E))

C First cell information is input from Table 17-H

    Population growth for remaining cells = first cell + (first cell * (Table 17-J))

D * = B * (Table 16-C) / 2,000 lb/ton

E * = C * (Table 16-G) / 2,000 lb/ton

F * = D + E

G * = D - I

H * = E - J

I * = D * (1 - (New Base Recycling Efficiency, [input New Loading-Table 16-AN]))

J * = E * (1 - (Community Recycling Efficiency, [input New Loading-Table 16-AO]))

K * = I - J

L * = E * 365 day/year

M * = a cumulative running total of (F)

N * = G * 2,000 lb/ton / initial compaction density

Table 19 Option Input - Input Parameters

		☐ ADC	▨ Shredder	☐ Compactor	☐ Compost	Exp. Slot
A	Input Parameters -					
B	Initial Cost of options ($)	$175,000	$200,000	$350,000	$10,000	
C	Life of Unit (yrs)	15	15	15	15	
D	Misc. Units	$6,000	$20,000	$0	$0	
E	Life of Misc. Unit (yrs)	3	5			
F	Sys Ops/Maint Cost ($/yr)	$2,000	$2,000	$3,000	$2,000	
G	Enter Option Variable	◀▶ 1 %	◀▶ 15 %	◀▶ 1,500 lb/yd^3	◀▶ 25 %	
H	% of Landfill Remaining	100%	100%	100%	100%	100%
	Initial Operations:					
I	Salary of Worker ($/hr)	$15		$15		
J	Number of Workers	1		1		
K	Worker time (hrs/day)	3		4		
L	days/year	365		365		
M	Sub-Totals: ($/yr)	$16,425	$0	$21,900	$0	$0
	New Operations (1):					
N	Salary of Worker ($/hr)	$15	$15	$15	$15	
O	Number of Workers	1	1	1	1	
P	Worker time (hrs/day)	3	4	4	3	
Q	days/year	35	365	365	365	
R	Sub-Totals: ($/yr)	$1,575	$21,900	$21,900	$16,425	$0
	New Operations (2):					
S	Salary of Worker ($/hr)	$15				
T	Number of Workers	1				
U	Worker time (hrs/day)	0.75				
V	days/year	330				
W	Sub-Totals: ($/yr)	$3,713	$0	$0	$0	$0
X	New Ops. Totals: ($/yr)	$5,288	$21,900	$21,900	$16,425	$0

(Use of Expansion Slot: Write in name of option and all applicable alternative specifications.
The program will recognize this option once the 'Initial cost of options ($)' cell is filled.)

Table 19 – Footnotes

All Option Input entries required on this page pertain to investigating alternative landfill operations
(All cells requiring input are white in the main program)

A   Click on the alternative(s) of choice to select

B   Enter the capital cost of each alternative(s)

C   Enter the expected life of each piece of equipment corresponding to the alternative(s)

D   Enter the capital cost of each applicable sub-units (i.e., tarps, blades) for each alternative(s)

E   Enter the expected life of sub-unit(s) corresponding to the alternative(s)

F   Enter the Operations/Maintenance cost for each alternative(s)

G   Option variables have pre-set range, see corresponding sections in the main body of the thesis

H   * = 1 - (Input from Table 6-AQ)

J - N pertain to current (Initial) landfill operations

The following is an example of a landfill using soil for daily cover:

I   pay - $20/hr

J   1 person

K   3 hr/day

L   365 day/year

M   total annual salary = I * J * K * L

N - R pertain and S - W pertain to proposed changes resulting from alternative selection

Continuing with the daily cover example, New Operation 1: due to Guam weather, soil will still be required intermediately

N   pay - $20/hr

O   1 person

P   place/remove soil = 3 hr/day

Q   36 day/year

R   sub-total annual salary = N * O * P * Q

S   pay $20/hr

T   1 person

U   place/remove tarp = 0.75 hr/day

V   329 day/year

W   sub-total annual salary = S * T * U * V

X   New operation annual salary = R + W

Table 20 Option Input – Output Parameters

	Output Parameters		
A	Costs Annualized/new life ($/yr)	$9,091	
B	Misc. Annualized/new life ($/yr)	$3,636	
C	Initial Life of Landfill (yrs)	18.5	
D	Initial Capacity Landfill (ton)	88,449.5	
E	Initial Annual cost of worker	$0	
F	No. Machines to buy over new life	1	
G	No. Misc. to buy over new life	4	
H	New Life of Landfill (yrs)	21.8	
I	New Weight of Landfill (tons)	104,058.3	
J	New Annual cost of worker	$21,900	
K	Net Weight realized (ton)	15,609	
L	Net Life realized (yr)	3.3	
M	Monetary gain of change	$1,404,787	
N	Annualized over new life	$64,341	
O	Not Feasible @ (% life remaining)	30%	
P	Annual Salary Savings	-$21,900	
Q	Expenditures	$36,627	
R	Balance	$27,714	
S	Option Feasibility Status	Feasible	

All Output parameters are calculated on the cost analysis page (no inputs are required in this Table)

A	Input from Table 22-G
B	Input from Table 22-H
C	Input from Table 22-L
D	Input from Table 22-M
E	Input from Table 22-O
F	Input from Table 22-P
G	Input from Table 22-Q
H	Input from Table 22-R
I	Input from Table 22-S
J	Input from Table 22-T
K	Input from Table 22-U
L	Input from Table 22-O
M	Input from Table 22-W
N	Input from Table 22-X
O	Input from Table 22-AG
P	Input from Table 22-AF
Q	Input from Table 22-Z
R	Input from Table 22-AE
S	* If no alternative selected, then n/a; if R > 0 "Feasible"; if R < 0, "Not Feasible"

Table 21 Option Input – Contractor Input Parameters

A	☐ Contract	
B	Annual Cost	$100,000
C	Community Pop.	5,000
D	Comm. Per Capita	4.00
E	Comm. Pop growth	0.0%
F	Tipping fee ($/ton)	60
G	expansion slot	

Provides the user an opportunity to analyze a contract option to include community MSW and an investigation of alternative operations.

(All cells requiring input are white in the main program)

A Click on the alternative if the goal is a contract effort

B Enter the annual cost of a contract

C If community MSW will be included enter the population

D If community MSW will be included enter the waste generation per capita figure

E If community MSW will be included enter anticipated population growth

F Proposed tipping fee

G (additional expansion slots may be added here, currently not a functional slot)

Table 22 Cost Analysis Calculations

Header annotation blocks:
- Left input block — "input from Option Input"; "smallest # > zero"; "Annual Generation" — values: 0% ; $9,012 ; $27,714
- Column AF block — –21900 ; 30% ; 3.3 ; 15,609
- Right block — "Worker Savings"; "Break Even Point"; yr (extension) ; tons (more to fill)

Ref	Description	AC	AD	AE	AF	AG	AH	AI
A	Initial Procurement Cost ($)	$200,000						
B	Life of Unit (yrs)	15						
C	Misc.	$20,000						
D	Life of Unit (yrs)	5						
E	% of Landfill Life Filled	0%						
F	% of Landfill Life Filled	0	5	10	15	20	25	30
G	Annualized over new landfill life ($/yr)	$9,091	$9,524	$10,000	$10,526	$11,111	$12,500	$13,333
H	Misc.: Annualized over new life of fill	$3,636	$3,810	$4,000	$4,211	$3,333	$3,750	$4,000
I	Operation/Maintenance Cost	$2,000	$2,000	$2,000	$2,000	$2,000	$2,000	$2,000
J	Annual Contract Cost	$0	$0	$0	$0	$0	$0	$0
K	Sub-Total	$14,727	$15,334	$16,000	$16,444	$16,737	$18,250	$19,333
L	Initial Life of Landfill (yrs)	18.5	17.8	16.8	15.8	14.8	13.9	13.0
M	Initial Capacity Landfill (ton)	88,449.5	85,088.4	80,493.8	75,583.7	70,821.9	66,360.1	62,113.1
N	Regression Equation	100%	96.2%	94.6%	93.9%	93.7%	93.7%	93.6%
O	Annual cost of worker	$0	$0	$0	$0	$0	$0	$0
P	No. Machines to buy over new life	1	1	1	1	1	1	1
Q	No. Misc. purchase over new life	4	4	4	4	3	3	3
R	New Life of Landfill (yrs)	21.8	21.0	19.8	18.6	17.5	16.4	15.3
S	New Weight of Landfill (tons)	104,058.3	100,143.7	94,699.4	88,893.8	83,283.8	78,008.6	72,981.0
T	New Annual cost of worker	$21,900	$21,900	$21,900	$21,900	$21,900	$21,900	$21,900
U	Net Weight realized by change (ton)	15,608.8	15,055.3	14,205.6	13,310.1	12,469.9	11,648.5	10,867.9
V	Net Life realized by change (yr)	3.3	3.2	3.0	2.8	2.6	2.4	2.2
W	Monetary gain of change	$1,404,792	$1,354,975	$1,278,504	$1,197,911	$1,122,291	$1,048,363	$978,111
X	Annualized over life	$64,440	$64,610	$64,571	$64,404	$64,131	$63,925	$63,929
Y	Cost of Worker Savings	-$21,900	-$21,900	-$21,900	-$21,900	-$21,900	-$21,900	-$21,900
Z	Expenditures	$36,627	$37,233	$37,900	$38,637	$39,194	$40,150	$41,233
AA	Generation	$64,341	$64,341	$64,341	$64,341	$64,341	$64,341	$64,341
AB	Balance	$27,714	$27,108	$26,441	$25,704	$25,147	$24,191	$23,108

(This process continued through 100 percent)

Table 22 (Continued)

AJ																			
0.0%	5.0%	10.0%	15.0%	20.0%	25.0%	30.0%	35.0%	40.0%	45.0%	50.0%	55.0%	60.0%	65.0%	70.0%	75.0%	80.0%	85.0%	90.0%	95.0%
AK																			
100.0%	95.0%	94.7%	94.5%	94.1%	93.7%	93.4%	92.8%	92.3%	91.6%	90.3%	90.7%	88.9%	87.5%	85.7%	83.4%	79.9%	75.0%	66.7%	50.0%
AL																			
99.5%	96.2%	94.6%	93.9%	93.7%	93.7%	93.6%	93.2%	92.6%	91.8%	90.7%	89.6%	88.5%	87.3%	85.9%	83.9%	80.5%	74.9%	65.6%	50.5%

Program Regression Equation

$$y = -6.6491x^6 + 7.5349x^5 + 4.0015x^4 - 9.1556x^3 + 4.3852x^2 - 0.8413x + 0.9946$$
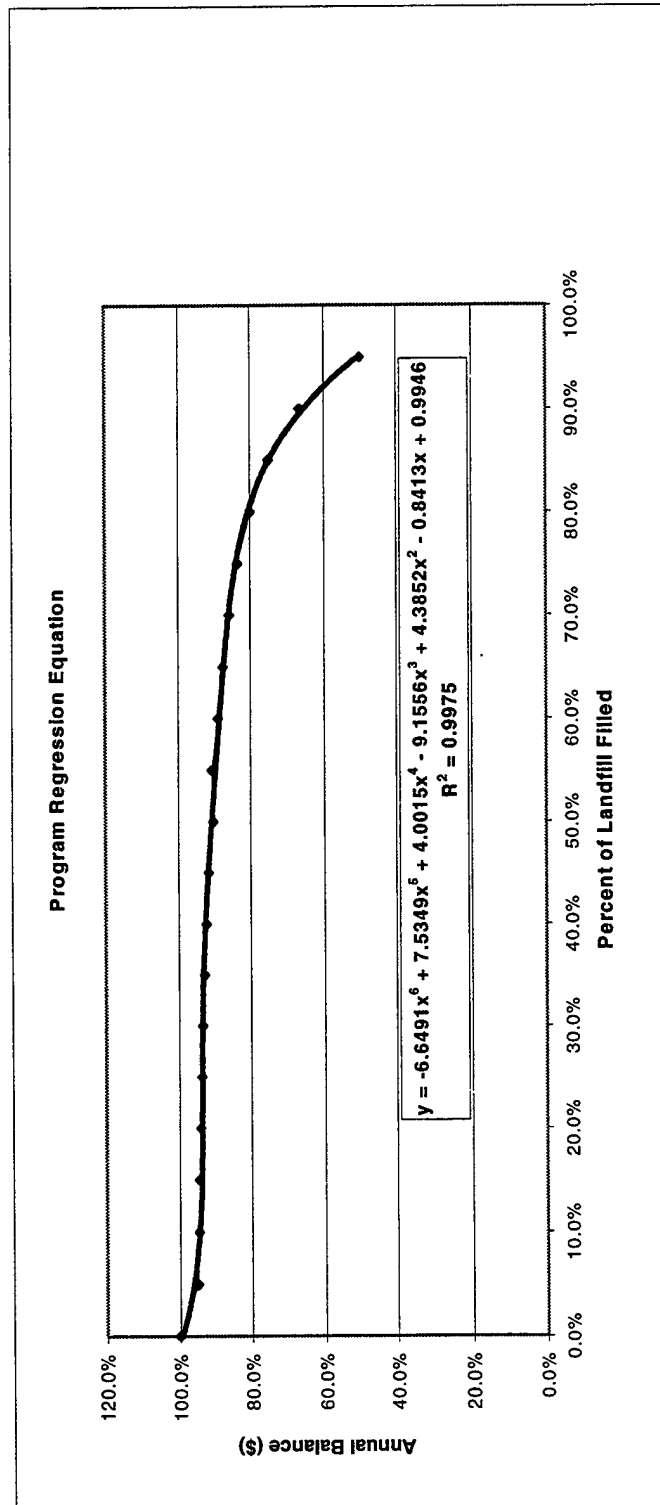$$R^2 = 0.9975$$

Figure 1 LEM Program Regression Equation

Table 22 – Footnotes

(no inputs are required in this table)

A * = sum of all 'Initial Cost of options ($)' inputs on Option Input page

B * = average of all 'Life of Unit (yrs)' on Option Input page

C * = sum of all 'Cost of Misc. Units ($)' inputs on Option Input page

D * = average of all 'Life of Misc. Unit (yrs)' on Option Input page

E * = entered values from 100% to 0%

F * = Input from Table 6-M

G Cost of equipment annualized over new life of landfill = B * N / P

H Cost of misc. equipment annualized over the life of the landfill = D * O / P

I * = sum of 'Sys Ops/Maint Cost ($/yr)' on Table 19-F

J * = Cost of annual contract input from Table 21-B

K Expenditure Sub-total = G + H + I + J; if contract option, Table 21-A is not selected, the associated annual fee will not be included

L * = initial life of landfill, input from Table 6-G

M * = initial volume of landfill yd³ * initial compaction density of MSW lb/yd³ / (2,000 lb/ton)

N sixth order regression equation calculated (xx); = (-6.6491*X⁶)+(7.5349*X⁵)+(4.0015*X⁴)-(9.1556*X³)+(4.3852*X²)-(0.8413*X)+(0.9946)

O * = Initial annual cost of worker salaries, input from Table 20-E

P * = round (number years of landfill extension / expected life of machines), =round(R / B)

Q * = round (number years of landfill extension / expected life of misc.unit), =round(R / D)

R * = new life of landfill, input from Table 13-I

S * = new volume of landfill yd³ * new compaction density of MSW lb/yd³ / (2,000 lb/ton)

T * = New annual cost of worker salaries, input from Table 20-J

U * = net weight realized by change, = S - M;

*If contract selected, population entered, no options selected - maximum community weight New Calcs sheet * 365 days/year * R

V * = net life realized by change, = R – L

W Monetary gain realized by change in new weight

If contract selected, population entered, no options selected = U * Option Input-Contracting-Tipping Fee; If contract selected, population entered, options selected; = (U * New Loading-tipping fee) + (max. community wt. New Calcs sheet * 365 day/year *landfill life)

If no contract selected, options selected = U * New Loading tipping fee

X Monetary gain annualized over life; if contract selected, population entered, no options selected = U * Option Input-Contracting-Tipping Fee; otherwise = U * New Loading Tipping fee / R

Y Savings associated with the 'Cost of Workers' = O – T

Z Expenditures = K

Table 22 – Footnotes (Continued)

AA Generation of funds = X + Y

AB Balance = Y – X

AC Current life remaining on landfill; input from Option Input page

AD * = code to look for the smallest balance greater than zero

AE * = Based on the results of AB will return the corresponding annual generation (Y) number for that percentage

AF * = Based on the results of AB will return the corresponding "Cost of Workers' savings (W) number for that percentage

AG * = Based on the results of AB will return the corresponding percentage of life remaining (F)

AH * = Based on the results of AB will return the corresponding net life realized by change (T) number for that percentage

AI * = Based on the results of AB will return the corresponding net weight realized by change (S) number for that percentage

AJ * = Entered values from 0 to 100 percent representing landfill filled

AK * = Correction Factors based on landfill design specification

AL * = Sixth Order Polynomial Regression Equation generated below; number are input in row N

$[(-6.6491 \cdot X^6)+(7.5349 \cdot X^5)+(4.0015 \cdot X^4)-(9.1556 \cdot X^3)+(4.3852 \cdot X^2)-(0.8413 \cdot X)+(0.9946)]$

Regression Analysis

Option Input   Remove Trendline   Add Trendline

$y = -3372956.218x^4 + 5124607.389x^3 - 2452602.236x^2 + 379929.497x + 139541.220$

$R^2 = 0.956$

Percent of Landfill Filled

Annual Balance ($)
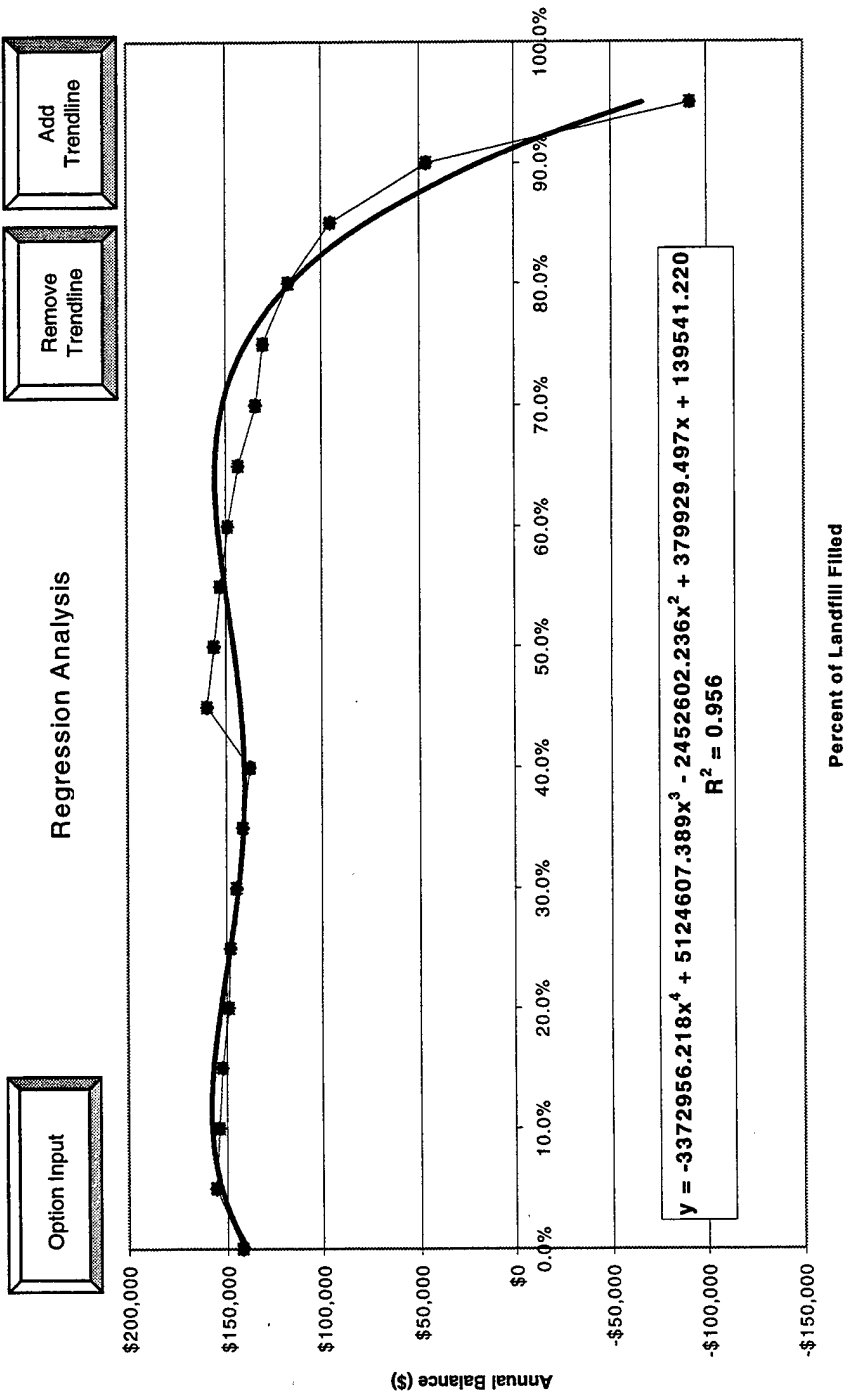
Figure 2 Regression Analysis for Shredding Option

Regression Analysis – Footnotes

The regression analysis will calculate a fourth order regression equation. It is important to note this function is only applicable for a new landfill with nearly 100% capacity remaining. All analysis performed on the AAFB landfill is made based on 100 percent capacity remaining.

Prior to using the regression analysis sheet - press the "Remove Trendline" button.

Once the alternative(s) have been selected return to the regression sheet and press the "Add Trendline" button.

Based on the specifications entered in the program a fourth order regression equation will be generated. An operator can use this equation to find the annual balance in terms of dollars [Y] is feasible at any percentage of landfill life remaining [X] by solving for X.

Table 23 Master Recycling Program - Waste Stream Analysis

Base Recycle Program Component	% by weight	no recycle ton/day	recycle Rate	adjusted ton/day	Sell Price $/Ton	no recycle lb/month	recycle diverted lb/month	recycle efficiency %
Program Balance =			$122,461 Annual Gain			Efficiency calculator if lb/mo known		
Max Generated Ton/Day 20.1375								
Food Wastes	17.5	3.5	0.0%	3.5	$0.00	211,444	0	0.0%
Containers								
Aluminum	2.0	0.4	90.0%	0.0	$0.23	24,165	0	0.0%
Bi-metal/tin	3.1	0.6	0.0%	0.6	$0.00	37,456	0	0.0%
Glass	10.4	2.1	95.0%	0.1	$0.00	125,658	0	0.0%
Plastics	1.1	0.2	0.0%	0.2	$0.00	13,291	0	0.0%
Subtotals	16.6	3.3	70.4%	1.0		200,570	0	0.0%
Paper Products (other than containers)								
Cardboard	8.4	1.7	95.0%	0.1	$10.00	101,493	0	0.0%
Paper/Magazines	5.1	1.0	75.0%	0.3	$10.00	61,621	0	0.0%
Mixed	19.4	3.9	0.0%	3.9	$0.00	234,401	0	0.0%
Subtotals	32.9	6.6	35.9%	4.2		397,514	0	0.0%
Plastics (other than containers)	10.1	2.0	0.0%	2.0	$0.00	122,033	0	0.0%
Scrap Metals (other than containers)	1.6	0.3	75.0%	0.1	$0.00	19,332	0	0.0%
Wood								
Pallets/Crates	2.0	0.4	100.0%	0.0	$0.00	24,165	0	0.0%
Other wood	1.6	0.3	0.0%	0.3	$0.00	19,332	0	0.0%
Subtotals	3.6	0.7	55.6%	0.3		43,497	0	0.0%
Dry Cell Batteries	0.2	0.0	0.0%	0.0	$0.00	2,417	0	0.0%
Miscellaneous								
Construction Debris	1.9	0.4	100.0%	0.0	$0.00	22,957	0	0.0%
Diapers	4.2	0.8	0.0%	0.8	$0.00	50,747	0	0.0%
Glass (other than containers)	0.2	0.0	0.0%	0.0	$0.00	2,417	0	0.0%
Rubber (other than tires)	0.2	0.0	0.0%	0.0	$0.00	2,417	0	0.0%
Textiles (rags, clothing)	0.9	0.2	0.0%	0.2	$0.00	10,874	0	0.0%
Yard Waste (grass, fronds)	6.6	1.3	100.0%	0.0	$0.00	79,745	0	0.0%
Other	3.5	0.7	0.0%	0.7	$0.00	42,289	0	0.0%
Subtotals	17.5	3.5	48.6%	1.8		211,444	0	0.0%
Totals:	100.0	20.1	20.1	13.1	overall	211,444	35.2% recycle efficiency	

Table 23 – Footnotes
(All cells requiring input are white in the main program)

A Components of the MSW stream
 Max generated ton/year; input from corresponding Initial and New Calculation sheets
 Overall Recycling Efficiency = [1 - (last row column E / last row column D)]

B User may input new values in the appropriate blocks of this column, only make changes after a completion of a waste stream analysis
 This information was input based on information obtained from the AAFB Solid Waste Management Plan
 Program balance = input from AH and AI

C * = A * (B / 100); (i.e., Food Waste comprise 17.5% or 3.5 ton/day out of the generated 20 ton/year)

D User may input values in the appropriate blocks of this column; (i.e., diversion of yard waste = 100%)
 Note: The Food Wastes, Recycle Rate, in the New Base Recycling program is linked to the Option Input page; see compost option

E * = C - (1 - D); (i.e., Glass has a recycle rate of 95% - [2.1 - (1 - .95) = .1])

F User may input values in the appropriate blocks of this column; (i.e., cardboard is selling for = $10/ton)
 The efficiency calculator can be used to calculate recycle efficiency numbers for D

G * = C * 30 day/month * 2,000 lb/ton

H User may input monthly recycle or diversion stats here

I * = H / G; corresponding recycle efficiency will be shown here, enter this information in D

J Calculates the overall recycling efficiency
 * = Total Adjusted ton/day (E) / No Recycling ton/day (C)

Table 24 Master Recycling Program – Recycling Cost Analysis

	1	2	3	4	5	6	7	8	9	10	11
A	100%	Time Invested Numbers are OK									
B	Recyclable Material	Recycle	Cardboard	Wood Pallets	Glass	Aluminum	Scrap Metal	paper/mag	Yard waste	C&D	compost
C	Equipment	Program	bailer	chipper	crusher	bailer		bailer			
D	% time investment in specific area	100%	25%	5%	15%	20%	10%	10%	10%	5%	0%
	Operations, Maintenance and Equipment Expenditures										
	Operations										
E	Labor (ex. 2 contract workers)	$90,000	$22,500	$4,500	$13,500	$18,000	$9,000	$9,000	$9,000	$4,500	$0
F	Training	$1,000	$250	$50	$150	$200	$100	$100	$100	$50	$0
G	Administration	$1,000	$250	$50	$150	$200	$100	$100	$100	$50	$0
H	Supplies	$1,000	$250	$50	$150	$200	$100	$100	$100	$50	$0
I	(expansion slot)	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
J	Subtotal	$93,000	$23,250	$4,650	$13,950	$18,600	$9,300	$9,300	$9,300	$4,650	$0
	Maintenance										
K	Equipment	$3,000	$750	$150	$450	$600	$300	$300	$300	$150	$0
L	Facility	$3,000	$750	$150	$450	$600	$300	$300	$300	$150	$0
M	(expansion slot)	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
N	Subtotal	$6,000	$1,500	$300	$900	$1,200	$600	$600	$600	$300	$0
	Equipment										
O	Depreciation cost over life of item	$15,000	$3,750	$750	$2,250	$3,000	$1,500	$1,500	$1,500	$750	$0
P	Operational cost of equipment	$5,000	$1,250	$250	$750	$1,000	$500	$500	$500	$250	$0
Q	(expansion slot)	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
R	Subtotal	$20,000	$5,000	$1,000	$3,000	$4,000	$2,000	$2,000	$2,000	$1,000	$0
S	Total Expenditures	$119,000	$29,750	$5,950	$17,850	$23,800	$11,900	$11,900	$11,900	$5,950	$0
	Income generated										
T	Quantity Diverted from landfill		587	147	726	132	88	281	485	140	0
U	Monetary value-landfill space gained		$52,789	$13,230	$65,358	$11,907	$7,938	$25,303	$43,660	$12,569	$0
V	Monetary value from sale of item		$5,865	$0	$0	$30	$0	$2,811	$0	$0	$0
W	(expansion slot)										
X	Total generation		$58,654	$13,230	$65,358	$11,937	$7,938	$28,114	$43,660	$12,569	$0
Y	Total Generation - Total Expenditures Balance=		$28,904	$7,280	$47,508	-$11,863	-$3,962	$16,214	$31,760	$6,619	$0
Z	All information is provided on an annual basis		Gain	Gain	Gain	Loss	Loss	Gain	Gain	Gain	Even

Table 24 – Footnotes

(All cells requiring input are white in the main program)

A   A1 = sum (D2 through D11); A2 = Instructions for user - if A1 = 100% then "Time Invested Numbers are OK", otherwise "Readjust Time Invested Numbers"

B   B3 through B11 represent the typical recyclable materials

C   C3 through C11 represent the typical equipment used in the recycle process for each corresponding material

D   User inputs the time invested toward each recyclable material respectively

E-I   N2 through R2 - User inputs annual costs associated with each of the operations categories; All categories will automatically adjust to these entries (i.e., if 50% time was invested in cardboard, 1/2 of the operations costs would be attributed to cardboard recycling)

J   * = sum(E through I)

K-M K2 through M2 - User inputs annual costs associated with each of the equipment categories; All categories will automatically adjust to these entries (i.e., if 50% time was invested in cardboard, 1/2 of the maintenance costs would be attributed to cardboard recycling)

N   * = sum(K through M)

O-Q O2 through Q2 - User inputs annual costs associated with each of the equipment categories; All categories will automatically adjust to these entries (i.e., if 50% time was invested in cardboard, 1/2 of the equipment costs would be attributed to cardboard recycling)

R   * = sum(O through Q)

S   * = J + N + R

T   * = (C - E) * 365 day/year

U   * = T * current compaction density (input from Initial Analysis page)

V   * = T * sell price $/ton (Table 20 - F)

W   User may define an additional monetary gain from recycle program

X   * = sum(T through V)

Y   * = X - S

Z   if Y > 0 then "Annual Gain"; if Y < 0 then "Annual Loss"; otherwise "Break Even"

Table 25 Summary

	The Summary Page				
A	Options Selected	Sredding			
B	Expenses ($/yr)	$36,627			
C	Revenue ($/yr)	$42,441			
D	Sub Total ($/yr)	$27,714	Revenue - Expenses		
E	Landfill Extension	3.3	years		
F	New Landfill Life	21.8	years		
G	Base	$122,462	Annual Gain	Overall Recycling Efficiency	35.2%
H	New Base	$122,462	Annual Gain	Overall Recycling Efficiency	35.2%
I	Net	$0			n/a
J	Community	$0	n/a	Overall Recycling Efficiency	0.0%
K	NSPS regulation	0.0	ton NMOC/day	Tier 1	Instructions: Continue to monitor this output
L	Initial pipe integrity	1.8%	Within tolerance		
M	new pipe integrity	1.8%	Within tolerance		
N	Initial tip fee	$90	$/Ton	to recoup costs of $8M landfill sticker price	
O	New tip fee	$90	$/Ton		
P	Sub Total ($/yr)	$122,462			
Q	Total	$150,176	Income per year realized		
R	Status:	This Option Requires Further Consideration			

Table 25 - Footnotes
(No inputs are required on this page)

A A display of the alternatives selected by the operator, Input(s) from Table 19-A will be shown on this line

B Total costs associated with alternative(s) selected; input from Table 20-Q

C Total revenue generated by alternative(s) selected; input from Table 20-N + Table 20-P

D Balance of Revenue - Expenses or (C - B)

E The net affect the alternative(s) will have on the useful life of the landfill, Input from Table 5-L

F New life of landfill based on alternatives, Input from Table 20-H

G Total balance and overall efficiency input from Base Recycling Program page, see Table 23-J

H Total balance and overall efficiency input from New Base Recycling Program page, see Table 23-J

I The net balance for the base recycle program and overall efficiency, (H - G)

J Total balance and overall efficiency input from Community Recycling Program page, see Table 23-J

K Scholl Canyon Model, $M_{NMOC}=2^*L_o^*R^*(e^{-Kc}-e^{-Kt})^*(C_{NMOC})^*(3.595\times10^6)^*(1.101)$, based on result-indicates Tier and instructions

* = if Table 5.a-S = 0 and Table 5.a-T =0, then "Tier 1"; if Table 5.a-S > 0 and Table 5.a-T = 0, "Tier 2",

* = if Table 5.a-S = 0 and Table 5.a-T > 0, then "Tier Entry Error"; if Table 5.a-S > 0 and Table 5.a-T > 0, "Tier 3", Instructions

* = if "Tier Entry Error", then "Check entries on Initial Analysis page";

* = if # ton NMOC/day < 55 and "Tier 1", then "Continue to monitor this output"

* = if # ton NMOC/day >55 and "Tier 1", then "goto Tier 2 or implement gas control"

* = if # ton NMOC/day < 55 and "Tier 2", then "No action, Repeat test every 5 years"

* = if # ton NMOC/day >55 and "Tier 2", then "goto Tier 3 or implement gas control"

* = if # ton NMOC/day < 55 and "Tier 3", then "No action, Repeat test every 5 years"

* = if # ton NMOC/day > 55 and "Tier 3", then "Implement gas control procedures"

L Input from Initial Calculation page, if input <,= 5.0% then "Within tolerance", "Lower height of waste and/or reduce compaction density"

M Input from New Calculation page, if input <,= 5.0% then "Within tolerance", "Lower height of waste and/or reduce compaction density"

N * = 8x106 / initial volume of MSW (yd3) * initial compaction density (lb/yd3) / 2,000 lb/ton

O * = 8x106 / new volume of MSW (yd3) * new compaction density (lb/yd3) / 2,000 lb/ton

P sub total for the recycling portion of the analysis; = G + I + J

Q total for overall analysis; = D + N

R Status-if no alternative(s), "Only Recycling Considered Here"; or "Option requires further consideration", "Does not appear to be a good option"

EVALUATION AND RISK ASSESSMENT OF ALTERNATIVES

FOR EXTENDING THE LIFE OF LANDFILLS

CAPTAIN PHILIP J. PREEN AND Dr. R. JERRY MURPHY

CASE STUDY: ANDERSEN AFB, GUAM

PACIFIC AIR FORCE COMMAND

JUNE 1999

LANDFILL EXTENSION MODEL (LEM)

INSTRUCTION MANUAL

TABLE OF CONTENTS

1. SYSTEM REQUIREMENTS

A   Minimum requirements

(i) Microsoft Office 97

(ii) Microsoft Excel 97

B   LEM.XLS

(i) Less than 500 KB program

(ii) Standard high density 3.5 inch disk

2. HOW TO START THE LEM PROGRAM

A   Insert 3.5-inch disc in applicable PC slot.

B   Start Microsoft Excel 97

C   Under *File* chose *Open*

D   Select A drive

E   Click once on "LEM.XLS" then OK or Double Click on "LEM.XLS

F   At start up message will prompt for use of Macros.

G   Press the *Enable* Macros Button

Note: This program has macros installed to perform various functions.

3. PROGRAM PAGES

This manual was written to provide easy to use operating instructions for the LEM computer program. All supporting documentation may be found in the "Evaluation and Risk Assessment of Alternatives for Extending the Life of Landfills" thesis. The following sections outline the input requirements for each corresponding page of the program. Throughout this section references are made to the tables provided in Appendix 1 of the thesis. Although the following instructions correspond to the required input of each page in the program, operators may find it helpful to use the tables presented in Appendix 1.

3.1 Title Page

An introduction page to the main program. Press the *Index* button to continue.

3.2 Index

The index page is the hub of the program. From this page, access to all of the pages requiring input is possible. There is a brief description of each button provided on this page. Press any of the buttons to proceed. The user may also return to the *Title* page. Data may be input in any sequence, however, there is a recommended order for data entry:

A   *Initial Analysis* Page: Input the current operating conditions of the landfill.

B   *Base Recycling Program* Page: Input the current specifications for the base recycling program.

C   New Loading Page: Input the new/desired operating conditions of the landfill.

D   *New Base Recycling Program*: If a change is desired in the base recycling program it should be made on this page. This information will update along with the information entered on the *New Loading* page.

E   *Option Input Page*: Select any combination of 5 preset alternatives including a contract option. Note: If new compaction equipment is purchased insure the corresponding lift-slope information on the *New Loading* page is updated.

F   *Community Recycling Program*: When the contract option is selected the user may define the parameters of the community recycling program. This will be used if the community waste will be collected as part of the contract arrangement.

G   *Summary*: This page provides the "Bottom Line" for all information selected in the preceding steps.

3.3 Initial Analysis Page

The user defines the current operating parameters for the landfill (Appendix 1, Tables 5.a and 5.b). These parameters will encompass landfill and lift dimensions; base population and growth rates; landfill management parameters (i.e., compaction and daily fill); and percentage of landfill filled. All cells requiring input in the LEM program are white.

3.3.1 Input Parameters

See *Initial Analysis* page or Appendix 1, Table 5.a.

A   Footprint of usable landfill space, do not include the liner anchor distance, AAFB value = 6 acres

B   Shape of foot print, (i.e., square = 1:1 and 40 foot x 20 foot rectangle = 2:1), AAFB value = 1:1

C   Average depth of usable landfill space footprint, AAFB value = 4 foot

Taken from base of landfill to top of side slope

D   Construction specification of the liner side slope outlining the disposal area,

AAFB value = 3:1

E   Desired final height of completed landfill, AAFB value = 45 feet

F   Cover depth of final cover (cap system), AAFB value = 8 feet

G   Average depth of intermediate cover, value 0.5 feet

H   Base population currently living on base, utilizes base waste pickup system

I   Base waste generation, per capita, for each resident described above, value = 4.51 lb/person-day

J   Working dimension for terrace width if landfill height will exceed 50 feet (elevation), AAFB landfill will not exceed 50 feet, so 0.0 feet. If a value is added the program will evaluate the need for a terrace and utilize this number accordingly.

K   Percentage of landfill lost due to use of soil as a daily cover, typical value range is 10 to 20 percent. 15 percent is used in this report as a baseline.

L   Current level of landfill compaction; AAFB is currently using Caterpillar D-5
         tractors, with an attainable compaction range of 900 to 1,100 pounds per cubic
         yard. A value of 1,000 pounds per cubic yard is used in this report.

M   Anticipated annual population growth for base population, AAFB value 0.0
         percent.

N   Tipping fee derived from initial cost of landfill • MSW input projected for landfill

O   Shredding equipment in use? If "No" then 0.0 otherwise the typical additional
         space realized by shredding is 15 percent; current AAFB value = 0 percent

P   Current number of lifts completed: i.e., enter 1 if first lift is completely filled;
         current AAFB value approximately 0.0 percent.

Q   Percentage of current working lift filled: i.e., enter 45 if second lift is 45 percent
         filled; current AAFB value approximately 0.0 percent.

R   MSW input to landfill, AAFB value = 13.1 tons per day; Note – when a value is
         entered here the program will use it. This will over-ride the recycle portion of the
         program. If no information is entered here the program will use the population
         and per capita figures provided above. The output parameter section will display
         what MSW input the program is using.

S   Subtitle D, NSPS, Tier 2 monitoring result input, If Tier 2 monitoring was required
         the result of the sampling will be input here. The default for the Scholl Canyon
         Model is 4,000 parts per million.

T   Subtitle D, NSPS, Tier 3 monitoring result input, If Tier 3 monitoring was required
         the result of the sampling will be input here as an equation constant K. The
         default for the Scholl Canyon Model is 0.05 liters per year.

See *Initial Analysis* page or Appendix 1, Table 5.b.   Note: Lift 1 volume calculations are made using the input parameter information shown above.

U-AC   Balancing the lifts will require operator manipulation.   As the lift heights are entered, monitor the maximum height with Cap output parameter.   This value should be within one foot, but not to exceed, the maximum desired landfill height input parameter of Table 5.a entry E. If the lift number is less than or equal to the maximum number of lifts "OK" will be indicated. If the lift number is greater than the maximum number of lifts "N/A" will be indicated. Lift information is required for all lift blocks with an "OK". Heights may vary between lifts depending on operator requirements. AAFB slope ratio, dictated by the Cat D-5 tractors is 4:1. The slope heights used in this analysis were chosen arbitrarily.   Typical lift heights range from 8 to 12 feet.

AD   Subtitle D, NSPS, NMOC emission estimate variable required for Scholl Canyon Model. If applicable, enter the number of years the landfill has been closed. AAFB value = 0

3.3.2 Output Parameters

See *Initial Analysis* page or Appendix 1, Table 6. These output parameters are based on information provided in *Initial Analysis* Tables 5.a and 5.b. All calculations are made on the *Initial Calculations* page or *Base Recycling Program* page. The figures are imported from these sheets and no inputs are required in this Table.

Based on the input parameters specified above the maximum number of lifts and height of landfill will be determined.   A baseline landfill life will be calculated based on

the overall calculated volume with 100 percent life remaining. Information on the quantity of intermediate cover required is also provided in this table.

Once the lifts begin to fill a new life will be calculated based on the available landfill space remaining. An elapsed time will also be calculated by taking the difference between the baseline and this new landfill life.

A   Maximum number of lifts specified in the design of the complete landfill.

B   Height of the landfill above the ground minus the height of the final cover (cap)

C   Height of the landfill above the ground plus the height of the final cover (cap)

        Note: The program considers the first lift complete at surface grade

D   Landfill Input of MSW; calculated based on population input provided in Table 5.a, entries H, I and M, or Table 5.a entry R.

E   Cumulative MSW; the landfill capacity of the landfill in cubic feet and cubic yards

F   Cumulative Intermediate Cover; the quantity of intermediate cover required for the landfill in cubic feet and cubic yards; assumes (worst case) no intermediate cover removal between lifts

G   Time to Fill; based on input, compaction density and cumulative MSW capacity will calculate a time to fill in terms of years and months. This is the baseline time to fill the landfill based on the initial input.

H   Cumulative MSW based on amount of landfill filled; once the fill sequence is initiated the program will calculate a new time to fill based on volume remaining in cubic feet and cubic yards.

I   Time to fill; A new time to fill will also be calculated based on this amount filled, MSW input, compaction density and cumulative MSW capacity.

J   Elapsed time; The difference between G and I will automatically be calculated. The program will indicate if the change is a "Gain" or "Loss".

K   Space filled; Reflects the amount of landfill filled in Table 5.a, entries P and Q, in terms of cubic yards remaining to be filled.   Reduces the baseline cumulative MSW corresponding to data entered.

L   Overall Recycling Rate is input from the *Base Recycling Program* page.

M   Percent Landfill Filled; Based on the information in Table 5.a, entries P and Q, will return the overall percentage of landfill filled.

3.3.3 Initial Calculations

Access to information on this page is restricted and no input is required. The user may only view the logic used to perform the calculations.

3.4 New Loading

The user defines the new and/or desired operating parameters for the landfill on this page. This page is set up similar to the initial analysis page. Information pertaining to the proposed landfill extension design must be input from the Option Input page. The cells are color-coded corresponding to the alternative presented on the Option Input page. Outputs provide landfill life extension or loss based on data input.

3.4.1 New Input Parameters

See *New Loading* page or Appendix 1, Table 12.a. All cells requiring input are white in the main program. For ease of use, this table provides a quick reference of initial input values. This page is used when there may be a mission change. New data pertaining to base population, annual population growth, per capita and intermediate cover may be entered here. Since the landfill life is based on volume and compaction density the tipping fee will be directly proportional to the corresponding inputs. A new tipping fee will be calculated on the summary sheet for use here. New base and community landfill inputs may be entered in O and P. As in the Initial Analysis page, these numbers will override the values derived based on the corresponding recycling program information.

A   Input the new base population; gives operator flexibility to assess future mission changes.

B   Community Population; User defines this information on the *Option Input* page; Table 21, entry C, Program is set up to only consider a community collection program under a contracted option.

C   Base Growth; User may define future mission changes by entering a projected annual growth.

D   Community Growth; User defines this information on the *Option Input* page; Table 25, entry E.

E   Waste generation, Per Capita, for the base may be defined here. Future studies may reveal changes in the MSW generated by the base population.

F   Waste generation, Per Capita, for the community; User defines this information

on the *Option Input* page; Table 25, entry D.

G   Landfill Compaction; This input is controlled on the *Option Input* page; Table 19,

entry G, Compactor

H   Intermediate Cover; User may update intermediate cover usage to reflect actual

operations.   Since the computer assumes worst case (i.e., no cover removed

between lifts) this number may be 3 inches compared to 6 inches.   This would

indicate landfill operations are using 50 percent less intermediate cover.

I   New MSW input; The user may see what the computer is considering for the new

MSW input. If a value is entered in Table 12.a, entry O, it will be reflected here.

J   Daily Cover Loss; User defines this information on the *Option Input* page; Table

19, entry G, ADC.

K   Shredding Loss; User defines this information on the *Option Input* page; Table

19, entry G, Shredder.

L   Status; A quick reference to determine if the alternatives selected will result in a

net gain of landfill life.   If the change results in a gain the readout will be

"Feasible"   ·

M   Number of Lifts Filled; Reflects the inputs provided on the *Initial Analysis* page.

N   Tipping Fee in dollars per ton; User may input a new tipping fee here.   The

Summary page will give the user assistance in selecting an appropriate tipping

fee based on the new information.

O   Base Landfill Input; User may define a new MSW input in Tons per day. Current,

ongoing analysis may redefine the daily input. Entering the information here will

bypass the *New Base Recycling Program* page information.

P   Community Landfill Input; User may define a community MSW input in Tons per day. Entering the information here will bypass the *Community Recycling Program* page information.

See *New Loading* page or Appendix 1, Table 12.b. All inputs required on this page pertain to the desired "New" landfill operations. All cells requiring input are white in the main program. As in the Initial analysis page, lift 1 calculations are made using the information in Table 5.a, entries A and D.

Q-Y   Balancing the lifts will require operator manipulation. As the lift heights are entered, monitor the maximum height with Cap output parameter, Table 13, entry C. This value should be within one foot, but not to exceed, the maximum desired landfill height input parameter, Table 5.a, entry E. If the lift number is less than or equal to the maximum number of lifts "OK" will be indicated. If the lift number is greater than the maximum number of lifts "N/A" will be indicated. Lift information is required for all lift blocks with an "OK". Heights may vary between lifts depending on operator requirements. AAFB slope ratio, dictated by the Cat D-5 tractors is 4:1. The slope heights used in this analysis were chosen arbitrarily. Typical lift heights range from 8 to 12 feet. Note: Ensure updated slope ratios are entered for new compaction equipment.

3.4.2 New Output Parameters

See *New Loading* page or Appendix 1, Table 13. No inputs are required on this table. A new volume and landfill life is calculated based on the new information

provided. This life is compared to the landfill life remaining number calculated earlier. A comparison is made between these dates and the life "gain" or "loss" is displayed. The new cumulative volume of space will also be displayed as Cumulative – MSW.

A Returns the Maximum number of lifts specified in the new operations.

B Returns the height above ground minus the depth of the final cover (Cap)

C Returns the height above ground plus the depth of the final cover (Cap)

D Indicates the initial input of MSW considered

E Indicates the initial cumulative MSW capacity in cubic feet and cubic yards

F Indicates the initial cumulative intermediate cover required in cubic feet and cubic yards

G Indicates the initial "Baseline" time to fill the landfill

H New cumulative MSW capacity defined by the changes made in Tables 12.a and 12.b in cubic feet and cubic yards

I Original time to fill; If the landfill is new this number will be the same as found in Table 13, entry G. If the landfill is partially filled this number will reflect this status. See Table 6, entry I.

J Elapsed Time; See Table 6, entry J.

K The program will calculate the overall gain or loss of landfill capacity based on the new information input. A gain will be shown in L. A loss will be shown in M

N Recycle Rate – base; Indicates the overall recycling efficiency identified on the *New Base Recycling Program* page.

O Recycle Rate – Community; Indicates the overall recycling efficiency identified on the *Community Recycling Program* page.

3.4.3 New Output Calculations

Access to information on this page is restricted and no input is required. The user may only view the logic used to perform the calculations.

3.5 Option Input

The Option Input page includes four analysis sets to investigate the feasibility of alternative daily cover, shredding, compaction, and composting of food wastes. One option is preset to investigate contract activities. The user enters data on worker salary and time, equipment and maintenance costs to include life expectancies, and specifications pertinent to the option. Outputs provided cost analysis and landfill life extensions based on data input.

3.5.1 Option Inputs

See *Option Input* page or Appendix 1, Table 19.

A   Input Parameters; Left click on the alternative(s) of choice. To use the Expansion slot simply type the name and specifications of the alternative in the Exp. Slot space. The program will recognize this option once the 'Initial cost of options ($)' cell is filled.

B   Initial Cost of options; input the actual/anticipated capital cost of the equipment required for each of the options. If the Compost option is selected see important note at the end of section 3.6 Base Recycling Program.

     (i)   ADC: Tarp roller

     (ii)   Shredder: Flail hammermill shredder

     (iii)   Compactor: Caterpillar MSW compactor

     (iv)   Compost: Compost turner

C   Life of Units; input the operational life expectancy of each piece of equipment. The program will use the average of each of the numbers presented in this section.

D   Miscellaneous Units; input the costs associated with support equipment.

     (i)   ADC: Tarps

     (ii)   Shredder: Rotor, blades

     (iii)   Compactor: n/a

     (iv)   Compost: n/a

E   Life of Miscellaneous Units; input the operational life expectancy of each piece of equipment. The program will use the average of each of the numbers presented in this section. The user should equate the operational life expectancy of each alternative by adjusting the miscellaneous unit costs.

F   System operations/maintenance costs; User defines the anticipated annual operating costs associated with each alternative.

G   Enter the Option variable

     (i)   ADC   0 to 20 percent; 1 percent used in alternative analysis

                            This represents using soil 35 days per year.

     (ii)   Shredder   0 to 15 percent; 15 percent used in alternative analysis

     (iii)   Compactor   0 to 2,000 pounds per cubic yard, 1,500 pounds per cubic yard used in the alternative analysis.

     (iv)   Compost   0 to 25 percent; 25 percent used in the alternative analysis

Note: The compost option reflects a reduction in the food waste portion of the waste stream as shown in the *New Base Recycling Program* and *Community Recycling Program*.

H   Percent landfill life remaining; Input from the *Initial Analysis* page.

I   n/a

J-N   Enter the current manpower requirements for each alternative selected.

ADC Example: Soil is used as daily cover, 1 person is paid 15 dollars per hour to place and remove the soil over 365 days per year. It takes this person 3 hours per day to perform this operation.

O-S   Enter the new manpower requirement for each alternative selected.

ADC Example: Soil is used as daily cover 35 days per year and the other information is the same as J-N

T-Y   Enter any additional manpower requirements associated with each alternative selected. ADC Example: Using the tarp system, 1 person is paid 15 dollars per hour to place and remove the soil 330 days per year. It takes this person 45 minutes per day to perform this operation.

3.5.2 Contract Option Inputs

See *Option Input* page or Appendix 1, Table 21. This table allows the operator to analyze a contract option. This contract option may include accepting community waste as part of the overall waste stream. All cells requiring input are white in the main program.

A   Click on the box to select contract. After contract is selected the operator may select any combination of alternatives shown in Table 19.

B   Enter the annual cost of the proposed contract

C   If community MSW will be included enter the corresponding community populations

D   If community MSW will be included enter the corresponding waste generation, per capita, figure

E   If community MSW will be included enter the anticipated annual population growth

F   Enter a proposed tipping fee to charge the community population

G   The additional expansion slot is currently not functional.

3.5.3 Output Parameters

See *Option Input* page or Appendix 1, Table 20. All input presented in this Table was derived from the cost analysis page. No inputs are required in this Table. The following is a description of each of the outputs generated.

A   The capitalized costs are averaged over the new life of the landfill. The original life plus the "gain" of life expected by the alternative reflect this new life.

B   The miscellaneous costs are averaged over the new life of the landfill as described in A above.

C   The initial "Baseline" life of the landfill.

D   The initial capacity of the landfill multiplied by the initial compaction density.

E   Based on the alternative(s) selected will show the current manpower requirements.

F   Based on the average life expectancy of the equipment will show the number of pieces to purchase over the new life of the landfill.

G   Based on the average life expectancy of the miscellaneous equipment will show the number of pieces to purchase over the new life of the landfill.

H   The "New" life of the landfill based on the effects of the alternative(s)

I   The "New" capacity of the landfill multiplied by the new compaction density.

J   Reflects the total new manpower costs associated with the alternative(s)

K   The difference between D and I above.

L   The difference between C and H above

M   Reflects the dollar amount of the net capacity gained by the alternative(s)

        Net capacity multiplied by the new tipping fee.

N   The amount calculated in M is divided by the new life of the landfill.

O   This is the point in time where there is not sufficient landfill life remaining to make the alternative(s) cost effective.

P   The difference between E and J

Q   Expenditures; if contract is selected the annual contract cost will be displayed here; otherwise, the total annual costs input in Table 19, entries B, D and F, will be displayed.

R   Balance; the difference between N and Q

S   Indicates weather the alternative is feasible or not, Also indicates when no alternative is selected.

3.5.4 Regression Analysis

A regression equation can be used on any data provided there is 100 percent life remaining on the landfill. If less than 100 percent life remains on the landfill the first corresponding data points will be zero. This will skew the data and result in an erroneous regression equation. This sheet has two buttons the user may push to add a pre-set, fourth-order polynomial regression equation. To use the preset buttons follow these steps:

A   If a trendline is present on the regression analysis page, press the Remove Trendline button.

B   Press the Add Trendline button to obtain the corresponding regression equation. If the fourth order regression equation does not represent the data follow these steps:

C   If a trendline is present on the regression analysis page, press the Remove Trendline button.

D   Using the mouse, click once on the data line.

E   Click on *Chart* and Add *Trendline...*

F   Click on *Type*

G   Select *polynomial*

H   Select the desired *order* for your polynomial (2 through 6)

I   Click on *Option*

J   Select *Display equation on chart* to display equation on graph

K   Select *Display R-squared value on chart* to display coefficient of variation on graph

It is not necessary for the user to select a trendline to determine the breakeven point for any chosen alternative(s). The information may be read directly off of the graph. The user should use the graph any time the landfill is has less than 95 percent life remaining. All calculations made in this analysis consider AAFB has nearly 100 percent landfill life remaining.

3.5.5 Cost Analysis

Access to information on this page is restricted and no input is required. The user may only view the logic used to perform the calculations.

3.6 Base Recycling Program

The landfill operator may use this sheet to input the parameters governing the existing base recycling program. A calculator is provided to determine the percent diversion of any portion of the waste stream if the mass diversion is known. The user can input the economics of the base recycling center to determine the cost effectiveness of the program. This sheet is explained in detail in the report, see appendix 1-Tables 23 and 24. See applicable Recycling Program page or Appendix 1 – Table 23.

A   The component of the waste stream

        Maximum generated block inputs the maximum generated tons per day number
        based on the corresponding population and per capita figures input.

B   These number were based on a previous study conducted on AAFB and should
        not be altered until a follow-up study is conducted on the waste stream.

The overall program balance is provided on the top of this page to indicate the result of the *Recycling Cost Analysis* page.

C   Based on the maximum generated number (tons per day). This number is derived by multiplying B by the maximum generated tons/day. The sum of this column equals the maximum generated figure in tons/day.

D   The recycling rate was based on the same study and current data obtained from the base. 100 percent recycle rates indicate a near perfect diversion of the corresponding material. On the *New Base Recycling Program* and *Community Recycling Program* pages the food waste recycle percentage is input from *Option Input* Table 19, entry G, Compost.

E   The adjusted ton per day is calculated by multiplying C and D.

F   The user may input the current selling price for each corresponding material.

G-I   The efficiency calculator is useful for determining the recycling efficiency of each material.

G   Calculated based on C above

H   If the amount of material diverted from the fill is known in pounds per month it may be entered here

I   The efficiency is calculated by dividing H by G to determine the recycling efficiency.

J   The overall efficiency is calculated for the program and displayed here.

See applicable Recycling Program page or Appendix 1, Table 24.

A   Total of row D; indicates when 100 percent of the total time allocated toward the recycling effort is accounted for.

B   Name of the recyclable material

C   Equipment commonly used for the collection of the corresponding material

D   User should enter the amount of time allocated to each material collection in relation to the overall total time allocated toward the recycling effort.

E-J   Enter the associated annual costs pertaining to Operations.

K-N   Enter the associated annual costs pertaining to Maintenance.

O-S   Enter the associated annual costs pertaining to Equipment.

S   Reflects the total annual costs from E through R

         Note: If the recycling program is outsourced, enter the annual cost in E and leave the rest of the cells blank.

T-X   Income generated is based on landfill capacity saved multiplied by the tipping fee. Income is also based on the amount of material collected and the selling price entered in Table 23, entry F. The program will automatically make these calculations.

X   Reflects the total revenue generated by the recycling effort(s).

Y   Difference between S and X

Z   Indicates the status of each individual program.

D3 through D11 Enter the time allocated to each material collection as described in D above. The other cells are automatically calculated by multiplying this percent by the amount input in column 2. Important Note: If the compost option is chosen, D will need to be recalculated to account for the time spent in compost material collection.

3.7 New Base Recycling Program

To determine the impact of proposed change(s) to the base recycling program this sheet may be used. The user may input the desired specifications of the proposed change(s) to the base recycling program. The cost effectiveness of the plan will be calculated in the new loading pages.

3.8 Community Recycling Program

This option was provided for the user to evaluate the cost effectiveness of opening the landfill to the community. The landfill operator may input the specifications effecting the community recycling program. An assumption may be made the community waste stream is approximately the same as the base population.

3.9 Summary

The end result of the alternative(s) analysis is presented on this page. The proposed options and resulting economic forecast are provided. The user will also find an overview of the recycling analysis, new source performance standard for air emissions and equivalent stress placed on the leachate collection pipes.

A   Automatically reflects the alternative(s) selected

B   Indicates annual expenses associated with alternative(s) selected.

C   Indicates annual revenue realized by alternative(s) selected.

D   difference of C and B

E   Quick reference to years landfill was extended.

F   Quick reference to new landfill life

G   Balance for overall Base Recycling Program and associated recycling efficiency

H   Balance for overall New Base Recycling Program and associated recycling efficiency

I   Net difference between G and H balance and overall efficiency

J   Balance for overall Community Recycling Program and associated recycling efficiency

K   Based on depth of head of 1.5 (typical rainfall events for given region) and 1 foot (EPA regulatory depth) will indicate worst case leachate breakthrough times (L) through the bottom liner system.

M   Calculates the non-methane production from the landfill in tons per day. Based on this result and input provided in Table 5.a, entries S and T, will indicate the current Tier level. Instructions will be provided to the operator based on the above information as to how to proceed to remain in compliance with air emission standards.

N   Calculates the initial "baseline" stress on the leachate collection system pipes. If the calculated value is less the 5.0% the system is within tolerance. If 5.0 percent is exceed the compaction density or the overall height of the landfill will need to decrease.

O   Calculates the New stress on the leachate collection system pipes. If the calculated value is less the 5.0% the system is within tolerance. If 5.0 percent is exceed the compaction density or the overall height of the landfill will need to decrease.

P   Initial tipping fee is provided to indicate the necessary fee to recover the $8 million installation cost of the landfill based on the amount of material to be disposed.

Q   New tipping fee is provided to indicate the necessary fee to recover the installation cost of the landfill based on the new amount of material to be disposed.

R   The total costs associated with each recycling program addressed in G, H and J.

S   The total of D and R

T   If S is positive the program will advise further consideration of the alternative(s) selected. If S is negative the program will advise reconsideration.

Access to information on the New Source Performance Standards is restricted and no input is required. The user may only view the logic used to perform the calculations.

4. TROUBLESHOOTING

A Problem: Macros do not work

  Possible Cause: Macros were not Enabled at program start-up

  Solution: Shut down program and restart, enable macros

B Problem: Error message appears when Remove Trendline button is pressed

  Possible Cause: No trendline was present when button was pushed

  Solution: Push *End* button on Error message dialog box

VITA

Captain Philip Preen was born in Elk Grove Village, IL. His parents are William and Karen Preen. In 1982 he graduated from Deer River High School, MN, enlisted in the AF, and was assigned to Little Rock AFB, AR, on a Titan II Missile Combat Crew. In 1986 he earned an Airman Commissioning Scholarship and attended the University of South Florida. In 1990, he was awarded a commission and B.S. Electrical Engineering. From 1990 to 1993 he served as Biomedical Research Engineer at Brooks AFB, TX, and was awarded an U.S. patent for a medical aspiration device. From 1993 to 1998 he served as Bioenvironmental Engineer at Lackland AFB, TX and Cannon AFB, NM consecutively. In 1998 he earned an AF Institute of Technology scholarship for a M.S. Environmental Engineering and attended the University of South Florida. He has published and presented research papers to scientific and medical communities.